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Japan Report

SCIENCE AND TECHNOLOGY

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JAPAN REPORT

SCIENCE AND TECHNOLOGY

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ENERGY

REVIEW OF ORGANIC MATERIALS USED IN BATTERIES

Tokyo NIKKO MATERIALS in Japanese Oct 85 pp 29-33

[Article by Kunio Yonahara, manager of Material Department, Development Division, Meidensha Electric Manufacturing Co., Ltd.: "Organic Materials Used in Batteries"]

[Text] 1. Preface

The most familiar types of batteries which come to mind may be the dry cell as No 1 unit cell, No 2 unit cell, etc., and the lead battery used for starting an automobile. As organic materials used for such batteries, paints applied to the printing on the surface of a dry cell, and polyolefin resin used for the case or cover of lead batteries, can be counted. However, this is not the essential material of a battery, and is not the subject of this article.

A battery is a type of energy converter[1] having an anode and a cathode that cause a chemical reaction with electrolyte, and the energy generates electric current (Figures 1 and 2). Batteries using organic materials for the anode, cathode, and electrolyte are under vigorous research and development in many countries.

This research will be explained here in three parts. The first part is on the zinc bromide battery, which is a new type of power storage battery being studied by Meidensha as part of the Moonlight Project of MITI's Agency of Industrial Science and Technology. The second part is on the polymer battery and the third is on organic solid electrolyte applicable for thin film batteries, etc.

2. Zinc Bromide Battery for Power Storage[2]

The development of this battery started in fiscal 1980 as consignment research from the New Energy Overall Development Organization as a part of MITI's Moonlight Project. The first interim evaluation test of this battery was performed in November 1983 with the 1 kw class battery.

The development is presently progressing to 10 kw class battery.

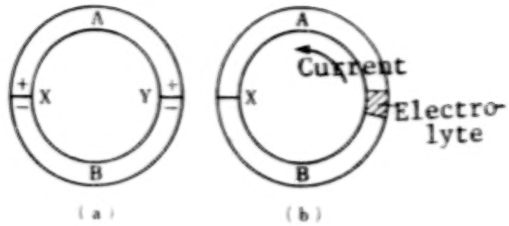

Figure 1.

Contact of two types of materials A and B as shown in (a) causes no electric current. However, insertion of electrolytic solution in one of the contact parts as shown in (b) will cause electric current to flow.

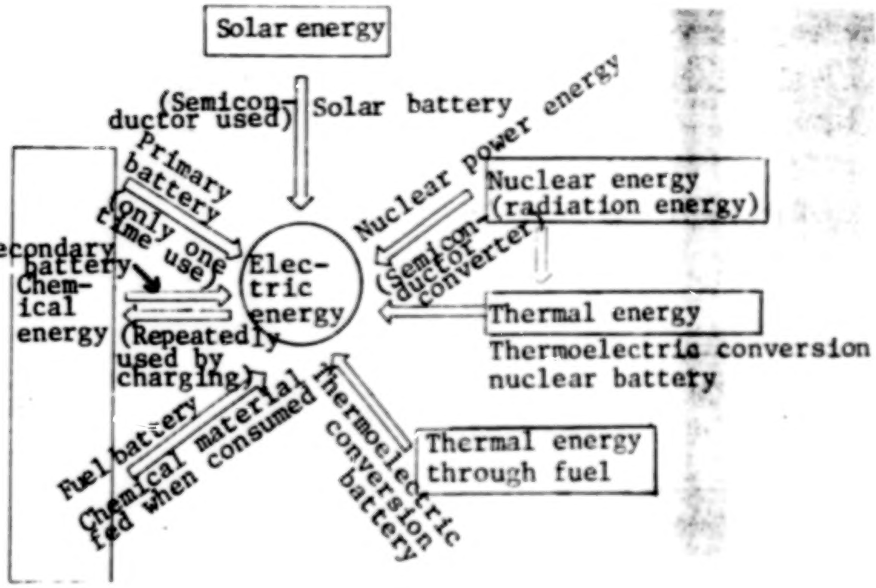

Figure 2.

Basic reaction of this battery is as follows:

(Anode)

$$2\,Br^- \underset{}{\overset{Q^+\cdot Br^-}{\rightleftharpoons}} Q^+\cdot Br_3^- + 2e^- \ : \ 1.06\ (V) \quad \cdots\cdots \tag{1}$$

(Cathode)

$$Zn^{2+} + 2e^- \rightleftharpoons Zn \ : \ -0.76(V) \quad \cdots\cdots \tag{2}$$

(Overall)

$$Zn^{2+} + 2\,Br^- \overset{Q^+\cdot Br^-}{\rightleftharpoons} Zn + Q^+\cdot Br_3^- \ : \ 1.82\ (V) \quad \cdots\cdots \tag{3}$$

In the above equation arrow marks to the right indicate charging, and to the left indicate discharging. Figures appearing on the right side of each equation indicate electromotive force at 25°C. Theoretical explanation drawing is indicated in Figure 3.

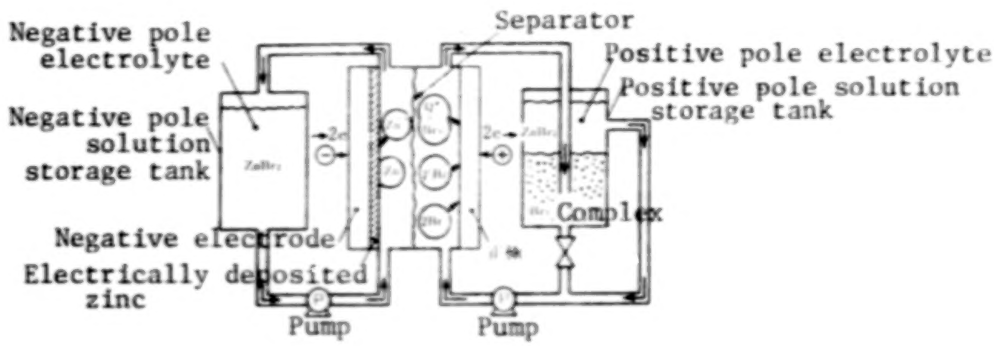

Figure 3. Principle Drawing of Zinc Bromide Battery (Charging status)

Special features of this battery are:

(1) High energy density and high output in comparison with existing batteries can be expected.

(2) The structure is simple.

(3) Both active materials are abundant and cheap from the viewpoint of raw material.

(4) It operates at ordinary temperature and is easy to maintain and store.

The electrolyte of this battery is aqueous solution of $ZnBr_2$, and most other materials, including electrodes, consist of organic materials or their composite materials. An example of the construction of the layer-built battery is indicated in Figure 4.

This battery utilizes a bipolar system of layers which consists of one side of the electrode as on anode and the other side as a cathode of the next cell.

The electrode is made of carbon-plastic developed as a composite material of polyolefin and carbon series material because of the corrosiveness of bromine generated during operation.[3] Details of the development of the materials and their characteristics have already been published,[3,4,5] so the gist is summarized in the following:

For the plastic electrode the following points were considered:

1) Volume resistivity will be reduced as much as possible,

2) Contact surface with the electrolyte will be made as large as possible (the side generating bromine is made to be porous),

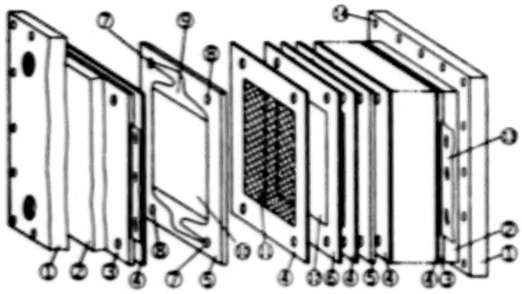

Figure 4. Elements and Construction of Layer-Built Battery

1. End plate for tightening
2. End plate for layer buildup
3. Electrode end plate
4. Packing
5. Framed membrane with MC
6. Intermediate electrode with flat plate frame
7. Manifold (anode)
8. Manifold (cathode)
9. MC formation
10. Membrane
11. Spacer mesh
12. Electrode
13. Collector mesh
14. Bolt holes for tightening

To reduce resistance, as much carbon as is practicable will be mixed at the plastic material. Carbon black, when its electric resistance is measured under pressure, has greater resistivity than graphite, but its resistivity can be reduced below that of graphite when it is mixed in plastics. Carbon black, however, cannot be mixed in plastics in as large quantity as graphite. Moreover, the addition of carbon black is limited for its molding characteristics, but inorganic fillers such as talc, calcium carbonate, silica, and graphite, can be added during the kneading process, and its volume resistivity can be reduced. The effects of calcium carbonate are shown in Figure 5 as an example.

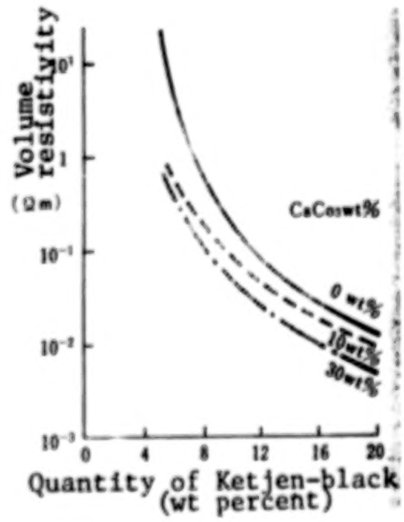

Figure 5. Electric Conductivity of Polypropylene Added With Ketjen Black EC and Calcium Carbonate

Many experiments were also carried out for the reduction of bromine permeability. Figure 6 indicates the data of experiment performed on high-density polyethylene. Figure 7 indicates the quantity of bromine permeance after 250 hours in the case of carbon black and graphite powder independently mixed in the polyolefin matrix. An electric conductive sheet as shown in photograph 1 [omitted] was developed based on the results of such experiments, and an electrode with characteristics as shown in Table 1 was obtained.

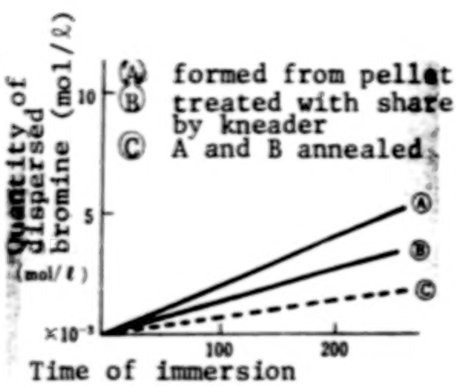

Figure 6. Bromine Dispersion in High Density Polyethylene

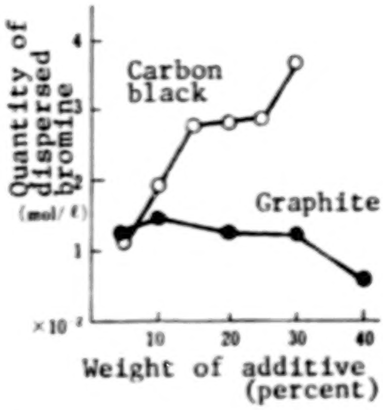

Figure 7. Quantity of Bromine Dispersion After 250 Hours

Table 1. General Characteristics of Electrode Plate

Item	Characteristic's requirements	Remarks
Plate thickness	1.0 mm	
Tensile strength	300 kgf/cm^2	No 1 Dumbbell
Volume resistivity	400 μΩm	4 probe method
Penetration of liquid bromine	0.01 mol or less	500 hours at room temperature
Coefficient of thermal conductivity	4 x 10^3 cal/cm•s•°C	Room temperature
Resistance to bromine	Pass immersion test in 95 percent liquid bromine	1,000 hours at room temperature

The first intermediate evaluation test of the 1 kw class battery developed as above was performed in November 1983 at the government industrial research institute, Osaka. The results were published along with that of batteries developed by other companies.[6] All participant companies are proceeding with the development for the second intermediate evaluation of the 10 kw class to be performed in the latter half of 1986. Photograph 2 [omitted] shows an external view of the trial-manufactured item of our company. It is planned

that demonstration tests will be performed in connection with the power supply system of the 1,000 kw scale with the batteries passed above intermediate evaluation test.

3. Polymer Battery

With the progression of research and development of electric conductive polymers, the polymer battery appeared with an important role in application development of those conductive polymer materials. Social environment requirements such as energy-saving, resources-saving, pollution problems (lead, mercury, etc.), etc. played a substantial role in bringing about the research and development. Much literature on the research and development of conductive polymers has been issued so far, but literature related to battery materials has been less than expected. The development in this field is still in the stage of basic research.

The polymer battery began with the research of the group of Professor Mac Diarmid (Pennsylvania University of the United States) by which the possibility of using polyacetylene (hereinafter called PA) as material for the electrode for rechargeable batteries was found.

A conceptual drawing and reaction equation of the PA-battery is indicated in Figure 8.[7] As seen in this drawing, Li^+ ion and ClO_4^- ion are doped to the cathode and anode, respectively. The doped ion will not escape naturally when the charging is stopped.[8] Electromotive force becomes constant at about 2.5 V, when doped for 1 percent or more.

During discharging, reverse reaction to charging will take place, and both poles will return to neutral PA, and return to the condition of ready to be charged.

Much research work was performed in the case of replacing the cathode of the PA-battery with Li, and in this case higher energy density will be obtained. Basically, other polymer batteries have only the difference of the electrode by which PA is replaced by other polymers.

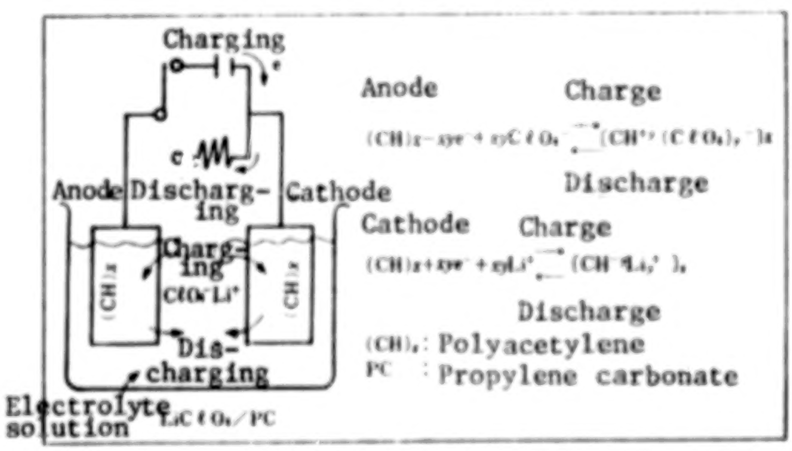

Figure 8. Conceptual Drawing of Polyacetylene Battery and Reaction Equation

Table 2 shows a comparison of the theoretical performance of the lead battery, nickel-cadmium battery, and PA battery. The cell voltage of the polymer battery is normally higher than the lead battery, and those which replaced PA with poly-para-phenylene indicates as high as 4.4 V. Numerals in the ( ) of the energy density column are dopant quantities, indicating more dopants by poly-para-phenylene battery, but the quantity reduced to per carbon atomic valence number is the same as the PA battery at about 6 to 7 percent.

Table 2. Theoretical Performance of Various Secondary Batteries

Constitution of electrode	Cell voltage (V)	Energy density (w·h/kg)	Maximum output density (kw/kg)
P-(CH)x/Li (Note 1) $LiClO_4$/PC (Note 2)	3.7	290 (6 percent)	36 (250 mA/cm^2)
P-(CH)x/n^-(CH)x $LiClO_4$/PC	2.5	150 (6 percent)	17 (120 mA/cm^2)
P-(C_6H_4)x/Li $LiPF_6$/PC	4.4	320 (40 percent)	(50 mA/cm^2)
P-(C_6H_4)x/$n^-$$(C_6H_4)$x $KAsF_6$/PC	3.3	150 (40 percent)	--
PbO_2/Pb H_2SO_4/H_2O	2.1	175	1.2
Ni/Cd KOH/H_2O	1.3	210	--
CP/CP (Note 3) $ZnBr_2/H_2O$	1.8	428	--

Note 1) Anode/Cathode Electrolyte/supporting liquid
Note 2) PC: Propylene-carbonate
Note 3) CP: Carbon plastic

Note 1) Polymer of $O = P \begin{cases} [(OCH_2CH_2)_{7-8}\ OCH_3]_a & a \leq 2 \\ (O\text{-}CH_2CH_2\text{-}\ OCOC\ (CH_3) = CH_2)_b & b \geq 1 \end{cases}$

Nobe 2) $\left\{ N = P \begin{matrix} OC_2H_4OC_2H_4OCH_3 \\ OC_2H_4OC_2H_4OCH_3 \end{matrix} \right\}_n$

Energy density is the value of the battery capacity divided by the total weight of the electrode and electrolyte, excluding the weight of the supporting electrolyte, collecting electrode, and casing. The energy density of a zinc bromide battery is very large, but the electrolyte solvent liquid cannot be eliminated. The practical energy density per weight is, therefore, in a range of about 10 to 20 percent of the theoretical energy density. The energy density of the polymer battery can be increased significantly when the quantity of dopant is increased.

So far polymer batteries have been explained placing importance on PA, but batteries adopting the conductive polymers poly-para-phenylin[9] and polyaniline[10] as electrode materials have also been studied. Particularly, batteries with a polyaniline electrode are also being studied seriously in the United States, and their practical application is expected.

Further, the conductive polymer material is also expected to be applied to the primary battery (a battery which cannot be recharged such as the dry battery) in addition to application to the secondary battery (a battery which can be charged and discharged, repeatedly) thus far explained. The Li-graphite fluoride battery applying the first stage graphite intercalate item is a well-known example of success. The second stage example of using $(C_2F)_n$ has also been reported.[11]

In any case, the polymer battery is far superior in energy density and power density to the lead battery. Moreover, the material is excellent in workability. Because it is plastic, it allows selection of freer configuration. Use of a large amount of dopant, development of a polymer electrode which will not deteriorate through the charging and discharging cycle or electrolyte liquid which prevents oxidation by overcharging will be big adantages in future use.

4. Solid Electrolyte

It has been explained that $LiClO_4$, etc., dissolved in an organic solvent of good acid resistance such as PC (propylene carbonate), THF (tetrahydrofuran) or acetonitrile are used as electrolyte liquid. However, these organic solvents may also start to deteriorate when the voltage of 4 V is applied. It is thought that replacement of the liquid electrolyte with a solid will improve the status. Solidification of the electrolyte is advantageous for the totally sealed fabrication of the battery so the electrolyte never leaks. It further prevents moisture or oxygen in atmospheric air penetrating into the battery and deteriorating the electrode and electrolysis. Some examples of the research will be shown below[12,13]:

The battery shown in Figure 9 is of the $(CH)_x$/PEO-NaI/$(CH)_x$ series, and the power density is as low as 10 to 20 w/kg. Maximum power density of the Na/PEO-NaI/$(CH)_x$ series is as high as 250 w/kg. Therefore, it seems that the internal resistance of the former battery will be high. The electrolyte of the (CH)x/PVDF·$LiClO_4$·PC/(CH)x series[14] has a conductivity of 3×10^{-4}s/cm. The energy density of the battery is 6.5 wh/kg, and the maximum power density is 1.1 kw/kg. It seems that more room for improvement may exist in the adhesion technology between layers of PA and PVDF $LiClO_4$·PC film, etc. Solid electrolyte is prepared by making a hybrid structure of polymer such as poly methacryloil oligo (oxymethylene)[15] poly (phosphate macromer)[16](Note 1), poly bis(2- (2-methoxy ethoxy) ethoxide) phosphasen[17] (Note 2), and $LiClO_4$, $AgSO_3$, and CF_3. Although being incorporated in batteries, these hybrid materials are still in the stage of research with problems in that the ions move close to the electrode, the resistance of the electrolyte changes and there is difficulty in continuation of the charging and discharging cycle.

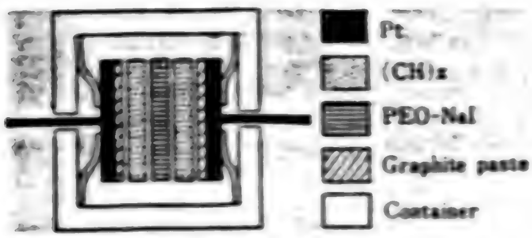

Figure 9.

However, new lower-resistance, solid electrolytes are being developed yearly, and when an electrolyte with a very low damping time of direct current ion conductivity is found, the development of a very thin film secondary battery can become practical.

5. Conclusion

The present status of research on the use of materials, especially organic material, in the zinc bromide battery, polymer battery, and solid electrolyte were reviewed above. However, these developments are in stages of basic research in every field, and it is yet to be forecast what type of battery will be eliminated and what type will be developed. However, organic materials, including graphite, are very promising battery materials as commodities, including automobile application, and will appear by the year 2000.

FOOTNOTES

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NEW MATERIALS

DEVELOPMENT TRENDS IN NEW MATERIALS REPORTED

Tokyo JIDOSHA GIJUTSU in Japanese Aug 85 pp 858-865

[Article by Hidehiro Kimura: "Development Trends of New Materials"]

[Text] 1. Introduction

It may well be a TV program of the NHK broadcast in January 1982, that made the term "new raw materials" popular and had them making a topic of conversation even in the living room of an ordinary household and, thus, touched off a state of fervor; the material was presented there as constituting one of the large-scale high technologies that brace up the nation, a nation which is to base its prosperity on industrial technology. In the program was seen a vehicle, mounting a ceramic engine developed by the corporation Kyosera, completing successfully a road test run of 30 km in Kagoshima. People then reacted to the report with a surprise and wondered how an engine made of crockery can run; nevertheless, a substantial number of ceramic products, e.g., scissors, nailclippers, and sporting goods have become readily available in our daily life presently.

The year 1984 then saw discussions on new materials emerge particularly in copious quantities because the policy for the fiscal year 1985 of the Ministry of International Trade and Industry [MITI] placed weight on new materials as the major target of developmental research and, in connection with this move, various relevant reports and research data were made public in succession by many advisory committees set up for the relevant purpose.

By way of example, in March 1984, the Industrial Structure Council of the relevant ministry, in a report, estimated the market scale of new materials at Y5.4 trillion in the year 2000, up from Y500 billion In the year 1981, that of products related to new materials at Y4.8 trillion, totaling Y10.2 trillion. If one allows for the production inducing effect of the material, the market for the relevant new products is estimated at Y20.3 trillion, the market for the products that replace old ones at Y21.3 trillion, and the value for manufacture of material induced by the new materials at Y11.2 trillion (including intermediate materials necessary for producing the above Y10.2 trillion of material); the total will thus expand to as enormous an amount as Y63 trillion.

Another of the examples is the report made by the Forum for the Basic Problems for Fine Ceramics, an advisory organ for the director of the Consumer Goods Industry Bureau of MITI in March 1984. The market scale of fine ceramics in the year 2000, according to the report, was estimated at Y2.8 trillion to Y4.2 trillion, up from Y630 billion for fiscal 1983. Various policy proposals, besides the above, have been made by an association for the research of new materials of the same ministry and by an association of the same name, of which the members are made up of private corporations and which is chaired by Haruo Suzuki, president of Showa Denko K.K.

There has emerged, as can be seen, a growing expectation and attention on new materials among both the government and private sectors.

2. Definition of New Materials

According to the definition of the nongovernment association for the research of new materials, the new material denotes material which can yield new absolute values, i.e., performance, function, and characteristics, and new social values, i.e., applications on the basis of metallic, inorganic, or organic raw materials or a combination of these by the use of new manufacturing and commercializing technologies. This concept is shown in Figure 1.

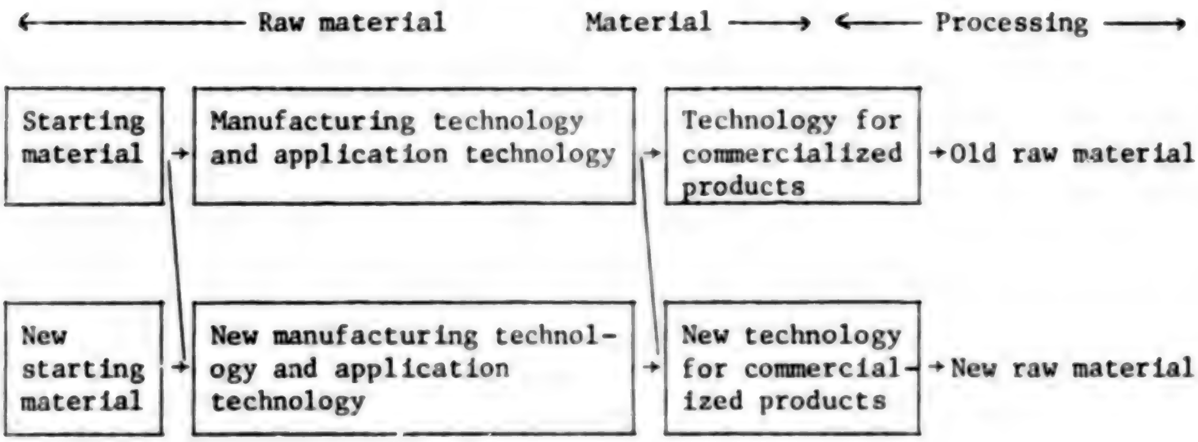

Figure 1. Diagram of the Concept of New Raw Materials

New materials, involving a great number of types, may be classified in many ways; one classification is based on the differences in material and function shown in Figure 2 (made by Kogin). Materials are classified largely by their physical properties, into inorganic materials that involve carbon as the major component and inorganic materials that do not. The inorganic materials are further subdivided into ionic-bonding and nonionic-bonding materials with the latter usually separated from the group and given an independent group, the metal material; still another category is the composite material which is a composite mixture of the above three substances. The new materials classified by functions, on the other hand, involve such categories as

Figure 2. Classification of New Raw Materials by Qualities and by Functions

[Key and explanation on facing page]

[Explanation of]
Figure 2. Classification of New Raw Materials by Qualities and by Functions
[Classification; Function; Examples of application (characteristics), examples of raw materials]

New raw materials

1. Inorganic materials

(1) Metallic materials

Electrical function--Solar cells (photoelectric conversion), amorphous silicon; high-speed calculation LSI's (high-speed electron mobility) GaAs; linear motor cars (superconductivity), nickel-titanium alloy and vanadium-3-gallium alloy
Magnetic function--Magnetic storage material (ferromagnetic), fine powder alloys and strontium-cobalt alloys; iron cores of transformer, magnetic head (high permeability); amorphous alloys
Mechanical function--Pipe joints (shape memory alloys), nickel-titanium type, copper-zinc type; materials for components of the precision machine and instruments (antivibratory effect), magnesium alloy; nuclear power equipment and aircraft and equipment (high-strength), nickel cobalt molybdenum alloy
Thermal function--Gas turbines and heat pipes (resistance to heat), nickel-based alloys and cobalt based alloys
Absorptive function--Hydrogen automobiles (hydrogen storage capacity), iron titanium type and magnesium nickel type

(2) Nonmetallic materials

Electrical function--IC packages (insulation), aluminum 2O3; resistance heating element (electroconductance), ZrO2, ignition devices (piezoelectric) ZnO, capacitors (dielectric property), barium titanium O3; varistor, gas sensors (semiconductivity), silicon oxide 2 and barium titanium O3; temperature sensor (ion conductivity), stabilized zirconium; electrode material for the electron gun (electron radiation), titanium carbide
Magnetic function--Ferrite magnets, magnetic tapes (magnetic property), barium strontium OG iron 2O3 and zinc manganese iron 2O3
Mechanical function--Cutting tools (cutting property), titanium carbide and tin.
Thermal function--Turbine blade engines (resistance to heat), aluminum 2O3, silicon carbide, and silicon 3 nitrogen 4; heat insulation material for nuclear reactors (heat insulation), potassium 2O titanium O2 and aluminum 2O3, heat radiation boards (heat conducting property), beryllium oxide.
Optical function--Laser diode (fluorescence), GaAs, niobium yttrium; sodium lamp (light-transmitting property), Al2O3AlON, MgO, optical fiber (light guiding property, SiO2.
Biological function--Artificial bone and tooth (adaptability to live tissue), Al2O3, apatite
Adsorptive function--Bioreactor (immobilization of enzymes), porous glasses; catalyst support (absorptive property), porous silica, Al2O3.

2. Organic materials

Polymeric materials

Electrical function--Printed circuit board and dielectric material for capacitors (insulation property), polyimide; electrodes (electroconductivity), doped polyacetylene
Mechanical function--Various types of structural materials (high strength), aramide fiber; material for speaker cones (high elasticity), polymer whiskers
Thermal function--Heat-resistant structural materials (heat resistance), polyamide-imide, etc.; cold-resistant rubber (resistance to cold temperatures), fluorine rubber
Optical function--Optical fibers (light guiding property), PMMA; photoresists and printing material for photography (photoreactive properties), resins which harden upon exposure to light
Biological function--Artificial blood vessels and artificial hearts (adaptability to organisms); silicon and fluorine resins; artificial soft tissues (adaptability to tissues), silicon resin; artificial kidney, acryl and metacryl types of resins.
Separative function--Gas separation films and reverse osmotic membrane (separation property), cellulose acetate
Catalytic function--Polymer catalysts, resin of superhigh strength; immobilized enzyme

3. Composite materials

(1) Polymeric type--Mechanical function--Aircraft and equipment, automobiles, ships, equipment for leisure time amusement, and sporting goods (high strength + light weight), epoxy resins, unsaturated polyester resins and polyimide resins for base materials; and carbon fiber, ceramic fiber, boron fiber, and aramide fiber for reinforcement materials
(2) Metallic type--Thermal function--Nuclear power related machines and equipment, gas turbines and aerospace machines and equipment (high strength and resistance to heat), Al, copper magnesium, titanium, and nickel for base material; and ceramic fiber, boron fiber, and whisker for reinforcement materials
(3) Ceramic type--Thermal function--Gas turbines, internal combustion engines, rockets, nuclear power related machines and equipment (high strength and resistance to heat), Al, Si carbide and Si oxide for base material and ceramic fiber, metal fiber, and whisker for reinforcement materials.

Source: data collected by Kogin

electrical, magnetic, mechanical, thermal, optical, biological, adsorptive, separative, and catalytic.

3. Background of the Emergence of New Materials

New materials ae emerging in succession and being spotlighted for the following two reasons: First, the requirement of the time for conservation of energy and resources across the world has led the Japanese economy to enter into a stage of reduction in weight and improvement in function of any industrial products so as to spend less raw materials; new materials adapted to this purpose are being sought after very much.

Secondly, technological and environmental conditions have grown mature enough to permit emergence of new materials; no matter how intensive the demand for it, the new material would not have emerged if it had not been for the technology development enough to make it possible.

Let us first examine reduction in weight of the economy, i.e., of industrial products. In Figure 3 is presented a plot for annual changes of the consumption of raw materials for every GNP unit, i.e., the consumption density for the period between the years 1955 and 1981 for major metals such as iron, aluminum, and copper. The consumption density, which represents the relationship between the rate of growth of a real GNP and that of the industrial raw material consumption, indicates here in this plot that the former has become larger than the latter since around the years 1950 to 1955. With the per capita GNP steadfastly growing in the Japanese economy, the consumption density is also steadily declining. Aluminum which represents industrial raw materials that have come to the market much later than iron, etc., has in contrast, seen its consumption density growing in parallel with the growth of per capita GNP. Whereas the consumption densities of iron, copper, zinc, and lead have long been declining, lightweight raw materials like aluminum exhibit the tendency to grow even after the oil shocks though the tendency has been made less remarkable owing to violent fluctuations of the relevant prices seen in recent years.

In an analysis of the problem in terms of the raw material for automobiles, one also sees that the average weight of automobiles of the United States, for example, has been declining rapidly from 1,798 kg in the year 1975 to 1,395 kg in 1980, and 1,087 kg in 1985. It is also notable that the unit weight of the materials is shifting toward lighter ones; the proportion of the plate of high tensile steel is predicted to rise to 16 percent, that of aluminum to 9.2 percent, and that of plastics to 13.7 percent (according to data from the Japan Automobile Research Institute). The trend is the same with Japan: The proportion of the plate of high tensile steel in all materials used rose from 0.5 percent in 1977 to 1.4 percent in 1980, and to 4.1 percent in 1983, that of block aluminum from 2.6 percent to 3.3 percent, and 3.5 percent for the corresponding years, and that of plastics from 3.5 percent to 4.7 percent, and to 5.7 percent. It is predicted that in 1992 the share of the plates of high tensile steel will grow to 26.5 percent, that of aluminum to 4.9 percent, and that of plastics to 9.1 percent.

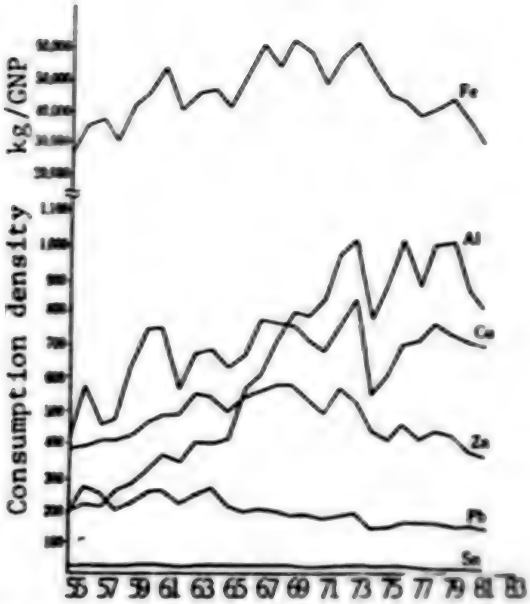

Figure 3. Trend for Lighter Industrial Products in the Japanese Economy (Consumption of raw material per Y100 million of real term GNP)

Let us now examine the matured technological and environmental factor, the second factor for the emergence of new materials. It is the aerospace industry that has exerted the major effect on the expansion of technology in connection with the emergence of new materials. Fine ceramics, carbon fibers, boron fibers, etc., have been brought out to meet requirements for raw material characteristics (excellence in lightness and strength, in resistance to heat, in low temperature characteristics, etc.) in connection with the manufacture of space shuttles, rockets, fighter planes, etc. The plate of high tensile steel which finds a wide range of application also in Japan in bridges, in steel frames, etc., as well as in the raw materials of vehicles, was developed, along with the relevant technologies for welding and processing, in connection with the development of a steel material for the chamber of the K-78 rocket during the years 1959-1965 and have a modulus of elasticity of 80-100 kg/mm^2. Another example connected with the aerospace industry is a technology for the manufacture of high pressure vessels made of a titanium alloy which was attained during the development of a second stage propulsion system for the N rocket.

Setting up of a space factory by means of space shuttles may be cited also as one example of the matured technological and environmental factor that provides an impetus to the emergence of new materials. The space factory, where substances and raw materials not obtainable on the ground are produced by making use of the space of the universe, now sees an era of full-fledged practical application of itself coming by virtue of the success of the flight (first in 1981) of the space shuttle which brought down a large measure the cost for the use of the space of the universe. Historically, the factory dates back to the end period of 1950 and turn of 1960 when Wensher, vice director of the raw material development division of the Marshal Space Flight Center of NASA, presented the relevant ideas.

Following an experiment in a small rocket in 1961 on weightlessness that continued for some 5 minutes and simple experiments made in Apollo spaceships 14 and 16, various experiments on raw materials such as ones on composite materials, alloys, electronic materials, and semiconductors were made in manned low-orbit spaceships including the Skylab and the Solute; in the experiments on an Apollo and a Soyuz, an experiment in connection with the coating of Si carbide whiskers with silver was suggested by Japan.

Development of new materials for electronics in connection with the maturation of the technological and environmental factor is as follows: Dielectric materials (for capacitors) saw the emergence of ceramics involving titanium oxide or salts of titanic acid such as magnesium titanate, and calcium titanate, toward the end of World War II and during the postwar period; the discoveries of these titanates were finally followed by that of barium titanate. Subsequently in around 1950, highly dielectric materials and an antiferroelectric material PZT, i.e., $Pb(Zr,Ti)O_3$, were developed and found practical application as piezoelectric material in filters and piezoelectric ignition devices. The theories on which to base the development of these electronic material, that is, the electromagnetic theories, meanwhile, had been furnished almost completely by the end of the 19th century and, besides, solid state physics, quantum theory, crystallography, etc., have made rapid advances since the 1960's. In parallel with these advances, relevant application and processing technologies have been improved; for example, $BaTiO_3$ which, in the pure state, exhibits great variation in dielectric constant with changes in temperature has its constituent replaced by Ca, Zr, or Sn. Products in thin film form, in superfi e particles, in superfinely divided forms, and in composite forms, and ones with high precision in dimension are other examples. There are some fine ceramics of which the functions and phenomena exhibited have been examined well, but for which theoretical elucidation of these functions and phenomena still remains to be made; it may be generally true, nevertheless, that basic research made on functions of individual raw materials and on new functions developed by combinations of these materials have contributed, in a large measure, to the emergence of new raw materials. In this way, the technological and environmental conditions have matured and emergence of new materials has been made possible.

4. Relations of New Material Technologies to Advanced Technology Industry

Advanced technology industries are braced up by a number of new raw materials; it will rot until the development of and progress in new materials have been made that the development of technologies for many of the high technology industries is made possible in the future.

A researcher of biotechnology, referring to the difference in maturation between the semiconductor technology and biotechnology, and comparing the difference to that of the time of the day, said that the former is at 11 am and the latter at 5 am. The degree of development of advanced technology industries as measured in time in this manner is pictured in Figure 4. The figure indicates that fine ceramics for use in structural materials, i.e., engineering ceramics, is at 4 am and still much premature and that

2 -

3 - Biotechnology (chemistry sector), space technology

4 - Biotechnology (agricultural sector), engineering ceramics

5 - Biotechnology (pharmaceutical sector)

6 - Bioceramics, optical processing machines

7 - Optical communication system, office automation, unmanned production facility system, i.e., factory automation

am 8 - Carbon fiber, aeronautics

9 - Engineering plastics

10 - Electroceramics, industrial robots

11 - Semiconductor, communication equipment

12 oclock - Large computers

pm

Figure 4. Times of the Day for High Technologies

the same material for use in electronics i.e., electroceramics, on the other hand, is mature at 10 am.

The requirements for and the use of new materials are classified by high technology sectors in Table 1. The sectors of electronics, biotechnology or biomimetics, optotechnology, new energies, and aerospace are cited as examples and one can immediately see, upon reviewing these, that fine ceramics is dominating other materials. In electronics, in the first place, they find use in IC base plates, in IC packages, and in various others as electroceramics. These uses are based on the properties of ifne ceramics, i.e., electrical properties, e.g., insulating piezoelectric, semiconductive, magnetic, and thermomechanical properties, e.g., resistance to heat, heat insulation, hardness and strength, resistance to abrasion. Biotechnology, in turn, sees alumina, apatite hydroxide, etc., finding use in artificial bones and teeth by virtue of the biological adaptability and mechanical properties of these materials. The sector of optotechnology is led by optical fiber (silica) followed by laser oscillators and optical functional devices, e.g., single crystals of lithium tantalate. The new energy sector involves materials of the nuclear fusion reactor, those of gas turbines, and those of ceramic engines among others; fine ceramics plays the major role in this sector because of their characteristic heat insulation and resistance to heat. In the sector of aerospace technology, finally, almost all reinforcements used in composite materials are fine ceramics of one type or another, and the heat resistant tiles covering the external surface of the body of the space shuttle are nothing but a fine ceramic.

Let us now compare the features and contents of three major technologies: a) electronics including technologies of semiconductors and computers; b) biotechnology; and c) new raw materials; as can be seen from Table 2,

Table 1. New Raw Materials Bracing Up High Technologies
(Classified by key technologies)

Key technology	New raw materials (examples)	Manufacturer corporations (in Japan) (examples)
Electronics	IC substrate (ceramics)	Kyocera, Narumi Pottery Corp., Japan Special Pottery Corp.
	IC package (ceramics)	Kyocera, Narumi Pottery Corp., Japan Special Pottery Corp.
	GaAs semiconductor	Sumitomo Electric Industries, Mitsubishi Metal, Showa Denko, Sumitomo Metal Mining
	Gadolinium-gallium garnet substrate (magnetic bubble storage material)	Shin Etsu Chemical, Hitachi Metal, Sumitomo Metal Mining, Tohoku Metal Industries, TDK, Mitsubishi Chemical
	Single crystal of silicon	Komatsu Electronic Metal Corp. Nippon Silicon, Osaka Titanium, (Kyushu Electronic Metal), Shin Etsu Semiconductor
	Amorphous silicon for solar cells	Sanyo Electric, Sharp, Fuji Electric, Matsushita Electric Industry, Asahi Chemical Industry, Teijin, Sumitomo Electric Industry, Taiyo Yuden Corp.
	Josephson device	Hitachi Central Research Institute (Densoken), (Musashino Communication Research Institute of NTT)
	Three-dimensional electric circuit device	Hitachi, Ltd., (Industrial Science and Technology Agency)
	Semiconductors of organic compounds	Dai Nippon Ink and Chemicals for makeup materials; Matsushita Electric Industries, Konishiroku Photo Industry, and Ricoh for photosensitive materials for use in electronic copiers
	Electrochromic device (ECD) (indicator or display device)	Nippon Paint, Sharp, Matsushita Electric Industry, Daini Seikosha, Nippon Kogaku
	Light transmitting ceramics (computer memory device)	NGK Insulator

[continued]

[Continuation of Table 1]

Key technology	New raw materials (examples)	Manufacturer corporations (in Japan) (examples)
Biotechnology (Biomimetics)	Artificial blood vessels	Unitika
	Artificial red cells (lysine based polyamide)	(Tokyo Science University)
	Collagen films	Koken (Medical Polymer Material Research Institute of Japan)
	Bismuth germanium oxygen (BGO) (for use in CT, and in X-ray detecting device)	Hitachi Chemical
	Artificial bone	Kyocera, Mitsubishi Mining and Cement
	Artificial tooth	Kyocera
	Films for water absorption and separation (synthetic rubber)	(National Chemical Laboratory for Industry of the Industrial Science and Technology Agency)
	Ion exchange resin	Asahi Chemical Industry
Optotechnology	Optical fibers (ceramics)	Sumitomo Electric Industry, Furukawa Electric, Fujikura, Hitachi Cable, Dainichi Nippon Cables, Showa Electric Wire and Cable
	Optical fibers (organic polymers)	Mitsubishi Rayon, Asahi Chemical Industry, Kanegafuchi Chemical Industry
	Optoelectric integrated circuit (OEIC)	
	a) Optical function devices	(Technology Department of Kyoto University)
	b) Optical bistable units or devices	Central Research Institute of Hitachi Ltd., (Tohoku University)
	c) Surface acoustic-wave device	Toshiba, Sanyu Ceramics
	d) Lithium niobate	Sanyo Electric
	e) Bismuth silicon oxide (BSO)	Ricoh
	Laser oscillator material (yttrium aluminum garnet or YAG)	NEC
	Multiple quantum well (MQW) semiconductor laser	(Musashino Communication Research Institute of the NTT)

[continued]

[Continuation of Table 1]

Key technology	New raw materials (examples)	Manufacturer corporations (in Japan) (examples)
New energy	Hydrogen storage alloys	Matsushita Electric Industry, Nippon Heavy Chemical Industry, Central Electric Industry, (Daido Steel), (Japan Vacuum Technology)
	Superconductivity material	Hitachi, Ltd., Toshiba, Mitsubishi Electric, NEC, Denki Kogyo, Furukawa Electric, Hitachi Cable, Sumitomo Electric Industry
	Alloys with extraordinary resistance to heat	Hitachi Metal, Kobe Steel
	Material for nuclear fusion reactors	(Kinzaiken of the Science and Technology Agency)
	Superfine particles of metals	Daido Metal, Mitsuitoatsu Chemical (Fuji Photo Film, TDK, Hitachi Ltd., Matsushita Electric Industry for magnetic materials)
	Ceramic engines	Kyocera, Nippon Special Pottery, NGK Insulator, Toshiba, Ishikawajimaharima Heavy Industry, Komatsu Ltd., Hitachi Metal, etc.
Aerospace	Carbon fiber	Toray, Toho Rayon, Sumitomo Chemical, Asahi Carbon Fiber, Mitsubishi Rayon
	Boron fiber	(Toshiba)
	Polyimide	Toray, Asahi Chemical Industry, TOYOBO Co., Ltd., Ube Industry, Mitsubishi Chemical Industry, Mitsui Petrochemical Industry, Unitika
	Silica tile (fine ceramics)	(DuPont, Lockheed)
	Aramide fiber	Teijin
	Alumina fiber	Sumitomo Chemical
	Silicon carbide fiber	Nippon Carbon
	FRM	Toyota Motor Corp.

[continued]

[Continuation of Table 1]

Key technology	New raw materials (examples)	Manufacturer corporations (in Japan) (examples)
	Silicon carbide whisker	Tokai Carbon
	Silicon nitride whisker (The materials cited above are reinforcements and base materials for composite materials)	Tateho Chemistry
	Shape memory alloy	Furukawa Electric, Kobe Steel, Mitsubishi Metal, Sumitomo Metal Co., Ltd.
	Unidirectional solidification blade	Ishikawajima Harima Heavy Industries
	Alloys of high performance involving a controlled crystallization	Ishikawajima Harima Heavy Industries

Table 2. Comparison of the Features of Three Major Key Technologies

Key technology	Electronics	Biotechnology	New raw material
Dawn of technology	Invention of the transistor of Shockley in 1948; invention of the IC in 1958	Discovery of a double spiral structure of DNA's in 1953	Development of ceramic package in 1950; discovery of an empla by DuPont in 1958
Basic principle	Physical science	Application technology based on biological science	Basic sciences i.e., physics and chemistry; application sciences, i.e, chemical, mechanical, and electronic engineering
Features of technology	Technology involving widespread application	One technology innovation rarely finds widespread application	Technologies relying on experience
Feature of the product	High degrees of freedom in the choice of raw material	An innovated technology, i.e., an advanced technology superseding the conventional technology, is applied in mass production	A new raw material technology is substantiated in products

[continued]

[Continuation of Table 2]

Key technology	Electronics	Biotechnology	New raw material
Effect on cost down	Learning curve effect works		Learning curve (experience) effect works
Productivity	Large boosting effect	Contributing to the improvement of productivity or production technology of the entire industry	Decline during the period of transition from conventional materials
Conversion of technology costs to capital buildup	Possible, providing the relevant technology stay at or above the general technology level of the time		Not easy
User industry	Entire industry	Agriculture, chemical industry, pharmaceutical industry, food processing industry	Electronics, automobile, aerospace, etc.
Extended effect on industrial structure	Initiating and pushing the development of the society of high grade information network	Effect exerted on the entire industries and on social structure; innovation of production process	Serving to brace up the other high technology industries
Hard- and software orientation	Hardware oriented	Software oriented	Hardware (plus software) oriented
Time of maturation	Maturation in progress	Maturation in the year 2000	Maturation not before the year 1990
Scale of equipment investment	Y50 trillion in the coming decade	Y2 trillion in the coming decade	Y3 trillion in the coming decade
Possibility of development of related industry	Industry for producing apparatuses for use in semiconductor manufacture, software industries	Industry for manufacturing machines and equipments, engineering industries like that of vegetable factory	Industry for manufacturing machines and equipment

[continued]

[Continuation of Table 2]

Key technology	Electronics	Biotechnology	New raw material
Factory siting	Industrial water, young and women labor force, access to airports and super highways, electric power, etc.	High quality water, access to airport and super highway access to universities (interdisciplinary buildup), etc.	Industrial water, electric power, interdisciplinary buildup, access to airport and super highway
Market scale	Y8.68 trillion in 1980; Y21 trillion in 1985	Y0 in 1983; Y100 billion or so in 1988; Y3-4 trillion in 2000	Y550 million in 1981; Y1.25 trillion in 1985
Growth	Over 20 percent per year		20-30 percent per year
Creation of employment	Small	Small	Small (capable of affording jobs to middle- and old-age workers and to physically handicapped workers)
International competition	The U.S. = Japan > Europe	The U.S. ≥ Japan ≥ Europe	The U.S. > Japan ≥ Europe
Hazard (Unfavorable effect on society)	Negative effect on employment		
Limitation in resources	Slight	Technology permits one to surmount the barrier of resource limitation	Raw material in abundance

they have many points in common, just as they show substantial differences in character in some respects. One example of the points they have in common is that these technologies burgeoned in the 1950's initiated by inventions and discoveries in, primarily, the United States: The IC was invented in 1958 and, where biotechnology is concerned, the double spiral structure of the DNA was discovered in 1953. In the case of new materials, ceramic packages, for example, were developed in 1950, the engineering plastics developed by DuPont Corp. in 1958, and the carbon fiber of the PAN type in Japan in 1959. To speak another way, the development of technologies for new materials has run parallel with that of advanced technologies of the other sectors.

The difference among the above three technologies, on the other hand, is one of the degree of advancement attained by each: electronics is just in the stage of full-fledged application and that of development into composite technologies, whereas biotechnology is barely getting to the stage of application. One sees the pharmaceuticals interferon and insulin, the first application products of biotechnology, put on the market of the West only as recently as toward the end of 1983, and Japan has yet to see even that. Where new raw materials are concerned, difficulties are involved in adapting developments to requirements since the material is very diverse in kinds, and even if the former meets the latter, either immature technologies for processing of the user make the bottleneck or, conversely, the manufacturer fails to provide a new raw material of adequate credibility in many cases, thus delaying practical application. Evidently, electronics far surpasses the other two sectors in the level of technology development.

As can be seen, the above three major technologies that brace up the advanced technology industries have points in common as they have points of difference.

5. Trend of the Development of New Raw Materials

Let us now consider the trend of the development of new raw materials. It holds true to not only new raw materials but also products involving advanced technologies in general that the incorporation of an advanced technology into an existing product generally permits it to possess an improved performance and, hence, high added value, high price, and high function. Under the circumstances, it does not make much sense if one compares simply a new product with the old since the contents of the products are different between the two.

The concept of price per kilogram is conceivable as a measure of the higher price and higher function of the product at this juncture.

The price per kilogram, by way of example, is Y100-200 for a raw material, Y1,200-1,300 for a Carola, an automobile, Y2,100-2,300 for a Soala, Y67,900 for VTR's, Y22,000 for compact disks, Y29,000 for word processors, Y17,000-25,000 for personal computers, Y200,000-300,000 for large computers, Y730,000 for the LSI of 64K RAM, and Y700,000 for jet engines. Where new raw materials are concerned, one sees the price of raw materials going up from Y100-200 per kilogram for the old material era toward Y1,000-10,000 per gram for an era of high value-addition, indicating a notable trend. The trend of new materials may also be displayed diagrammatically as in Figure 5. The figure presents, in a diagram, the trend of the decreasing consumption of industrial raw materials per unit of products [cars], which runs parallel with increasing degree of processing and fabrication. Each point in the figure represents the center of gravity for one group of materials as of the middle of the 1970's and each vector indicates the trend of the relevant material for the coming decade. The degree of complexity denotes the quantity of know-hows or softwares built up and incorporated in the relevant material or the products made from that material. All vectors have approximately the same bearing, i.e., toward lightness and

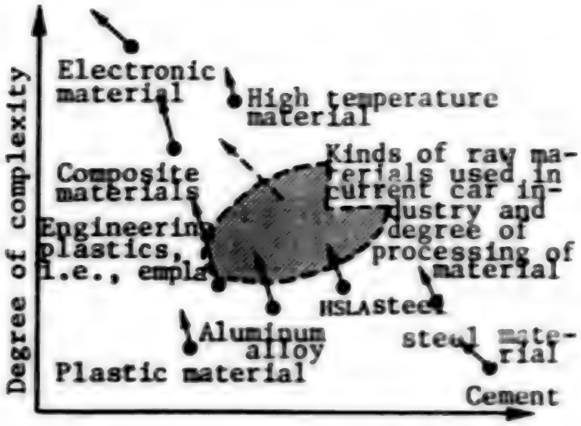

Figure 5. Future Trend of Industrial Material

Note: Every vector indicates approximately the same direction, that is, lesser consumption of raw material per unit weight of car and greater degree of processing.

higher value-addition, which is the very feature of the new raw material.

6. Contact Point Between the Manufacuturer and the User in Connection With the Development of New Materials

A fierce marathon race is being contested among a variety of corporations in connection with new raw materials. The author deals in this section with a relation of antagonism between the manufacturer and the use of new raw materials.

This relation must be best understood by taking the example of the new raw materials for use in automobiles. One finds here fundamental points of adverseness between the two as given below.

In the first place, the user, i.e., the automobile manufacturer sees its demand for a new material persistently increasing because of shortening the period of development for new products and shortening the lifespan of the commercialized products, whereas the maker of a raw material always faces a high possibility of having to ship its products without profits because its effort to reduce the cost of the raw material often fails to make up for the fall of prices of the product of the user. Secondly, where production is concerned, the user is more likely to use diverse kinds of new materials in limited quantities and, hence, harbors complaints that the relevant manufacturer is reluctant to comply with such orders, though the user is aware that the quantity of raw materials used per unit is too limited to make an adequate order. The manufacturer, in turn, likes the user to place an order of any material in large quantities and does not welcome orders for diverse kinds of materials in small quantity because these will not permit itself to make money at least for the time being. Thirdly, where new raw materials are analyzed

in terms of distinction strategy taken by corporations, the user bases their actions on the concept that "the distinction in products derives from the distinction on uniqueness of the relevant raw materials" and, hence, tries to produce the material on its own as far as it is possible. The manufacturer of raw materials, on the other hand, thinks that mere manufacture and sales of raw materials neither involve much value addition, nor bring in much profit and, hence, desires that its operation be extended to the phase of fabrication of finished products, or, further, to the phase of systematization of the products made from the new materials; here lies the actual possibility of competition between the two industries. Finally, where the basic concept for new materials is concerned, both the user and the maker have in common the concept that "one who controls raw materials controls everything"; nevertheless, the user harbors intensive demands for better raw materials on the ground that a uniqueness in finished products comes from nothing but a uniqueness in raw materials and, hence, makes exacting demands in orders placed to the users; the maker of raw materials in contrast, is obliged to be in an unfavorable position against the user in this connection unless it has an exclusive right of supplying the relevant raw material to the user.

As can be seen from this, there is a gap of interest between the user and the manufacturer of new raw materials which cannot be bridged; nevertheless, the automobile industry is sewing to the new material industry as the "Mother Industry" which takes care of the latter for growth, and the new material industry, in turn, is playing an essential role in the development of new technologies and new products by the automobile industry; it is apparent, therefore, that no progress can be expected in the future unless the two industries make effort in concert for technology development. It is worth emphasizing here again that it is the automobile industry and relevant technology that makes the contact point between the raw material (technology) and the design (technology) and that, hence, plays an extremely important role.

7. Recent Trend

In this final section, the author makes a general review on a) fine ceramics, which has attained the highest growth among the new materials and which has been in the spotlight throughout the year 1984; b) carbon fiber, a sector which Japan most favors; and c) engineering plastics.

7.1 Fine Ceramics

Of the fine ceramics, electroceramics has its technologies nearly completed whereas engineering ceramics sees its own only in the stage of R&D. As referred to at the beginning of this article, however, the market scale of the fine ceramics, based on the materials and the components in which fine ceramics are used, jumps from around Y630 billion for fiscal 1983 to Y1 trillion in the year 1988, to Y1.3 to 4.2 trillion at around the turn of the next century, as estimated in a report made by the forum for the basic problem of fine ceramics; corporations, at this juncture, are devoting themselves to getting as large a share as possible in this prospective market.

As for the moves of corporations for the year 1984, worthy of note is that cement makers in general, which were delayed in embarking on the relevant manufacture, had their production system improved in great measure. Mitsubishi Mining and Cement, having led the others in the production of "ring Varistor," a spark-arrester device for use in micromotors, "surge absorber" a voltage correcting device, and thermistor, among others, completed the second plant exclusively for ceramics manufacture in 1983 and embarked on the construction of the third in the fall of 1984, thereby displaying its aggressive attitude toward the relevant sector. Chichibu Cement Corp., following suit, is engaged in development and sale of products using its subsidiary Simarecs (ceramics spelled backwards). Onoda Cement Corp. and Nippon Cement Corp., meanwhile, have embarked on a full-fledged scale, on the manufacture of silicon nitride and silicon carbide since 1984.

Where ceramic engines, the major topic of conversation is concerned, the NGK Insulator Corp., since May 1984, has embarked on trial quantity production of a turbocharger rotor made of ceramic involving silicon nitride as the major constituent. The first component of the ceramic engine subjected to quantity production may reasonably be this turbocharger rotor.

The achievement in technology development for the past year in connection with the manufacturing technology of fine ceramics comprises: a) copper metallizing method developed by the government industrial research institute, Osaka, of the Industrial Science and Technology Agency, MITI; b) a method of electroplating copper directly on ceramic surfaces by Hitachi Chemical Co.; and c) a method of auto combustion sintering under pressure by Sumitomo Electric Industry and Osaka University, which is spotlighted as a method for reducing the manufacturing cost in large measure.

7.2 Carbon Fiber

The market of the carbon fiber of the PAN type grew expansively in the past. Though airline companies of the world curtailed their purchases of new model airplanes during 1982 and 1983 because of worldwide recession in the airline industry and, consequently, the carbon fiber which depends largely on the aerospace industry for its demand saw its production drop to some extent, the present recovery of the aerospace industry coupled with brisk demand from sporting goods and equipment for leisure-time amusement--80 percent of the demand for carbon fiber in Japan comes from these consumer products--will permit world production to rise to 2,200-2,400 tons annually from 1,800 tons for 1983. Japan, which produces some 70 percent of this production, will hold dominance in carbon fiber production in coming years.

The issue worthy of note in connection with the development of carbon fiber for 1984 is not for fiber of the PAN type but for that of the pitch type which uses pitches or residues of coal and oil as the raw material, whereas in the former types a synthetic fiber having been subjected to combustion is used as the material. One example is a fiber which was developed by Dai Nippon Ink and Chemical Inc. and Osaka Gas Co., Ltd., in a joint work in which a pilot plant was completed in June and from which samples are to be shipped this fall. Another is the construction of a small-scale plant

by Idemitsu Kosan Corp. for the production of a fiber which, according to the corporation, is to be priced at around Y2,000 per kilogram or only one-fifth to one-sixth as much as fiber of the PAN type. Hence, it will be extremely competitive. Still another is the development by Teijin Corp. of a fiber of an extremely high toughness and tensile strength, an improved modification of one developed 4 years ago by the government industrial research institute of Kyushu and involving spinning of material in an isotropic crystalline state, referred to as the premesophase, using as the raw material an ML pitch supplied by Nippon Kokan Corp.

Though the PAN fiber accounts for the major part of production of carbon fiber, the pitch type has the prospect of finding a wide range of application by virtue of its extremely low cost, providing its quality is comparable to the PAN fiber. Such major corporations as Toray Industries, Toho Rayon Co., Ltd., Mitsubishi Rayon, Mitsubishi Chemical, Asahi Chemical Industry, Sumitomo Chemical, Teijin, Nippon Carbon, Kureha Chemical Industry, Sumitomo Metal Industries, Ltd., and Toa Nenryo Kogyo are competitively engaged in development and sale of carbon fiber. Success in this venture depends on technological development and cost reduction.

7.3 Engineering Plastics or Empla for Short

The engineering plastics are superior to common plastics in resistance to heat, in resistance to tensile stress, bonding stress, and impacts, and in resistance to deformation, and used largely by virtue of their functions. Though the emplas are senior among the new raw material groups, the notable feature in their development for the years 1984-1985 is that the growth of special emplas and new emplas are gaining momentum.

Among the special emplas are: polyimide resin which is used in the space shuttle as a heat resistant material and which is produced in Japan primarily in film form; polyphenylon oxide resin which is a structural empla developed by GE of the United States and of which, following suit of the senior makers Engineering Plastics Corp. and Asahi Dow Corp., Mitsubishi Gas Chemical, Mitsui Toatsu Chemical, and Mitsui Petrochemical have since 1981 embarked on production; and econol which is produced and sold exclusively by the Sumitomo Chemical Co., Ltd., and which finds application in connectors for engines, electric and electronic products, and in sleeve components subjected to friction.

"Kanegufuchi Chemical Industry established technology for quantity production of polyimide film having extraordinary resistance to heat"; "Mitsui Toatsu Chemical embarked on quantity production of an adhesive agent of polyimide resin"; "Toray DuPont Corp. will embark on production of polyimide film developed by Dupont in Japan in 1985"; "Denki Kagaku Kogyo has developed a general purpose empla of the styrene type which is resistant to heat"--these are examples of information in newspapers cited at random on numerous reports on empla. It is out of the question that each corporation concerned is exerting itself to an extraordinary degree, but it may also be undeniable that the corporations are forced to develop new emplas

one after another because the users are demanding emplas of new functions, thereby relegating existing special emplas to simple general purpose ones.

One empla which has a prospect of increasing demand and on which corporations are taking great pains for R&D is the electroconductive plastic which permits passage of electric current. For example, by adding bromine to polyacetylene, one may convert the substance to a plastic with an electroconductivity halfway between the semiconductor and the metal, which may conceivably be available for batteries, electric wires, and materials that shield electromagnetic waves.

7.4 Trend for Other New Raw Materials

Exploration of application is underway for many other new raw materials not described above. An example of these are shape memory alloys, hydrogen storage alloys, and the Josephson element.

Finally, a noteworthy point in this article in terms of corporate strategy for the years 1984-1985 has been the setting up of research institutes or technology bases in the United States by Japanese corporations, or their plans to do so, appearing in unison. Kyocera Corp. is slated to set up operation of a large-scale plant for the manufacture of electronic components along with a research institute for new raw materials, particularly fine ceramics, in Vancouver, Washington, by the fall of 1985, if all goes well. Sumitomo Electric Industry is to construct a plant of optical fiber cables coupled with a research institute for optical fibers, GaAs, etc., to be located in North Carolina and slated to enter full-scale operation by late 1985. Kobe Steel Corp. is to set up a basis for technological information in the Research Triangle Park, North Carolina. Nippon Kokan announced plans to set up a joint venture in the United States for the manufacture of new raw materials of metals including titanium alloy in connection with the Martin Marietta Corp., a major manufacturer of aerospace related machines and equipment.

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CSO: 4306/3516

NEW MATERIALS

STANDARDIZATION OF TESTING, EVALUATION METHODS REVIEWED

Tokyo NIKKO MATERIALS in Japanese Jan 86 pp 18-22

[Article by Noboru Morishita]

[Text] Over the next 5 years, the Agency of Industrial Science and Technology, part of the Ministry of International Trade and Industry, will be promoting standardization (the establishment of standards in the Japan Industrial Standards [JIS]) of testing and evaluation methods in the three fields of fine ceramics, new organic composite materials, and new metallic materials. The purpose of this project is to make possible the mutual comparison of test data. By establishing JIS standards for these fields involving revolutionary new materials, the Agency of Industrial Science and Technology aims not only to react with flexibility in quickly establishing and modifying standards while taking into account users' needs and technological developments, but also to make international standards of the ISO (International Standards Office) a reality. The agency wants to seek the future direction for JIS standardization, with the Long-term Plan for Promotion of Industrial Standardization of the Japan Industrial Standards Research Council (an advisory body to the minister of international trade and industry) as a focal point.

Mutual Comparison of Data Desired

The Agency of Industrial Science and Technology sponsored the first general meeting of the ISO in Tokyo in September of last year. Due to the fact that the first Japanese ISO chairman, Isao Yamashita (vice chairman of the Keidanren and chairman of Mitsui Shipbuilding and Engineering Company Ltd.), was selected in 1986, this year can be called a fresh start for international standardization. Since the long-term plan proposed every 5 years by the Japan Industrial Research Council (chairman, Renzo Taguchi, chairman of the Japan Machinery Foundation) is being implemented in the context of the developments mentioned above, the proposals of the Agency of Industrial Science and Technology are receiving a lot of attention.

Let us consider the future tasks and direction with regard to the proposals concerning the field of new materials. First of all, an important future task is the standardization of the role of the technical base for ensuring mutual comparison of data by unifying material testing and evaluation methods. In

the past, the most basic theme of JIS standardization was the increase in productivity and the improvement of product quality in mining and manufacturing, but JIS standardization is not limited to such mature technical fields as this, but is also sought in rapidly advancing technical fields as well.

The Field of New Materials Is a Key Technology

Let us consider the trends in the technical development of new materials. It has been said that the present period is a new industrial revolution, and innovative technical developments in such fields as aerospace and information are progressing rapidly. However, the prerequisite for technical developments in these field is the development of new materials which can respond to high level functional and performance requirements. In other words, the field of new materials is a key technology.

The requirements of new materials are increasing, exemplified by the demand for lighter, stronger, and less costly materials. Of course, the development and application of fine ceramics, organic composite materials, and new metallic materials came about in response to such requirements. Let us look at the trends for each of these materials. In the field of fine ceramics, research and development is making rapid progress in oxide-based fine ceramics, as well as non-oxide-based fine ceramics, such as nitride-based, carbide-based, and carbon-based fine ceramics. In the area of functions, it is expected that a variety of materials will be developed having functions such as thermal and chemical stability, electrical conductivity, and ferroelectrical properties, as well as new properties which combine these functions.

In the field of new organic composite materials, the requirements are increasing in level and in variety, and developments are being made which will further increase the functional and performance levels. Highly functional polymer materials have been used in electrical materials, optical materials, photosensitive materials, separation membranes, etc., but there are many more applications to be researched and developed. Since highly functional polymer materials and high polymer composite materials have excellent thermal properties, mechanical properties, durability, and molding properties, progress is being made in applying them to many fields, including electrical and electronic parts, magnetic tapes, automobiles, and aircraft.

In the field of new metallic materials, progress is being made in the research and development of new metallic materials possessing physical functions such as shape memory, hydrogen storage, or the ability to change light or pressure into electricity, and chemical functions such as catalytic properties. These materials are called highly functional new metallic materials. On the other hand, the development of high performance new metallic materials is also progressing, with emphasis on requirements such as super heat resistance, super plasticity, high strength, high corrosion resistance, super conductivity, and vibration resistance.

Preconditions for Testing and Evaluation not yet Determined

The overall field of these new materials covers a wide range, from materials that have already achieved practical application to those that have yet to be researched and developed. In the future, these new materials will play an essential role in the development of advanced technologies such as electronics, mechatronics, new energy, and aerospace.

Since the prerequisites for testing and evaluation of the basic properties of these new materials have not yet been determined, there is a lack of reliability with respect to these materials, and there are obstacles to their smooth development and application. If both makers and users could test and evaluate new materials using the same methods, there would be no problem, but when users are deciding whether or not to use (purchase) new materials, they usually have their own tests. Thus, the lack of reliability resulting from differing methods of testing and evaluation hinders the development of applications of new materials.

It has therefore become essential to systematize and standardize (to establish JIS standards) testing and evaluation methods so as to permit mutual comparison of data. If such systematization and standardization becomes a reality, not only will it be possible to establish more trust between makers and users, but it will also become easy to determine the technological level of new materials, and it will become possible effectively to promote the development and application of new materials.

The Agency of Industrial Science and Technology recognizes that since new materials will be used to increase the level of advanced technological fields and to increase the level of a variety of products, the testing and evaluation of the materials will differ from that of past materials. These differences are as follows: (1) The level of the characteristics will differ; (2) The environments and conditions under which the materials will be used will be more rigorous; (3) The requirements for reliability will be high; (4) It will be necessary to evaluate quality in field conditions; (5) It will be necessary to evaluate quality from the standpoint of processing characteristics; (6) There will be a greater variety of tests and evaluations; and (7) The tests and evaluations will be more reliable. The standardization of testing and evaluation methods for new materials will be difficult if already standardized methods of testing and evaluating existing materials are used just as they are. It is thus considered necessary to develop new data bases and new testing methods for standardizations.

The Difficulty of Obtaining "Consistency"

Let us now consider the various items involved in the testing and evaluation methods that need to be standardized. JIS standardization should be conceived of in such a way that the system of standards is consistent. The types of standards include "Basic Standards," "Standard Methods of Testing and Evaluation," and "Product Standards." In the case of basic standards, plastic terminology standards (JIS K 6900) were established in 1977 for new organic composite materials, and efforts are being made to make this terminology consistent with that of the ISO (International Standards Organization).

Standards have been established for metals in JIS G 0203 (Steel Terminology--products and quality), but given the present state of development and application of new materials, it is necessary to unify terminology in all fields of new materials. For example, the term "delay fracture," referring to mechanical properties of structural materials, means "The phenomenon of a sudden brittle fracture of a material which has been used over a long period of time under static stress at room temperature, due to the influence of hydrogen," in the field of metals, but in the field of ceramics, it means "creep." In order to select materials based on their properties, there should not be contradictions among the definitions of the terms in each of the three fields of new materials. In order to avoid this, it is thought that before deciding on terminology in each of the fields, priority should be given to the establishment of JIS standards, since there is a need to standardize the terminology standards as one of the basic standards.

With regard to "Standard Methods of Testing and Evaluation," common testing and evaluation items will be established for all materials, since there are many classifications in the three fields. Furthermore, individual testing and evaluation standards will be common to all three fields, as in the case of basic standards, so as to simplify decisions regarding the potential use of a sample and its reliability as a material. Also, due to the partial revision of standards for existing materials, those that can be applied to new materials will be put to practical use.

It is hoped that standardization of "Product Standards," will proceed in a timely manner, with users' needs, trends in technology development, and trends in demand taken into consideration.

In the actual process of standardization, Basic Standards and Testing and Standard Methods of Testing and Evaluation will be given priority, in accordance with the timing of the establishment of JIS standards. Furthermore, the policy for JIS standardization will be to give priority to individual materials which are strongly desired by both makers and users, and which have already appeared on the market, and in the case of testing methods, priority will be given methods that will effectively promote the expansion of research and development of materials and the development of applications of materials. In the case of fields in which there is significant technological progress, speedy revision will be carried out so that the standard can be established and publicized in the necessary time period. Also, if necessary, schedules and proposals from stages prior to establishment of the standards will be made public as necessary to promote a progressive and flexible process of standardization.

In addition, research into foreign and domestic trends in standardization necessary to determine priorities for standardization will be improved and intensified. The aim of this research will be to organize data bases for test data and systematically to determine users' needs. Its application to internationalization is also considered important. Since it is expected that "friction" in the field of advanced technology will gradually increase in the future, the policy will be to make known both domestically and abroad the need for the establishment of JIS standards as well as their content, and to obtain

an international consensus, and also to propose the use of the JIS standards as international standards.

The Speedy Establishment of an Organization for Evaluation Proposed

The general direction of JIS standardization with regard to testing and evaluation methods for new materials has been indicated, but there still remains the task of organizing a system for carrying out the testing and evaluation in question. The more innovative the new material is, or the more limited its application, the more costly will be the equipment for testing it, and since the equipment will not be used so frequently, the cost of testing and evaluating new materials will be high. The use of testing and research facilities of national organizations such as the Agency of Industrial Science and Technology has of course been suggested, but the fact is that there are limits.

The importance of gathering and storing test data has been pointed out, but there is no suitable system for accumulating and making the data available.

It is clear that this is a problem that cannot be solved by a private enterprise on its own. In the field of materials, a Fine Ceramics Center has been set up as a foundation, but since the local industries in the Chubu region of Japan are very prominent in this project, it is not exactly the type of center that is needed. In the future, the use of public funds to establish centers such as the Fundamental Technologies Research Promotion Center, the cooperation of national and prefectural research laboratories and nonprofit foundations, as well as links between private companies and universities, and the establishment of other comprehensive systems to promote data gathering and dissemination will be an urgent task. It is expected that the establishment of testing and evaluation functions will become even more necessary as more new technologies are developed.

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CSO: 4306/3035

SCIENCE AND TECHNOLOGY POLICY

'BIG PROJECT' SYSTEM REVIEWED, IMPACT EVALUATED

System Overview

Tokyo KOGYO GIJUTSU in Japanese Dec 85 p 5

[Article by Seigo Sakakura, Technicians Council, Research Administrative Division, Agency of Industrial Science and Technology: "Big Project System Marks 20 Years"]

[Text] The large-scale industrial technology research and development system (the big project system) has passed the 20-year mark since its inauguration in 1966.

During this time, it can boast of having undertaken projects in 23 areas, of having achieved many technical results, and of having made a great contribution to the development of Japanese industrial technology.

The thinking at the time of inauguration of the big project system was to invest capital collectively in the research and development of large-scale systems where execution would be difficult for individual industrial areas. It is thought to have achieved fully its original purpose of gathering domestic English-Japanese technology and attempting technological breakthroughs.

We have attempted to accumulate the R&D management techniques used for big project administration and furthermore, the establishment of methods of supervising projects by cooperatively performing multiple undertakings has also proven valuable.

During this time in order to deal with energy problems the Sunshine Plan, started in 1974, and the Moonlight Project, begun in 1978, were made independent of the big project system and began to deal with energy technology development through similar systems. In 1981 the Next Generation Industry Basic Technology Research and Development System was inaugurated to develop basic technologies common to a number of industries. The R&D management techniques developed for the big project system have been used in these systems.

A number of technical results were also achieved under the big project system. Because of projects like "an ultra-high performance electronic computer," "the

desalinization of sea water and utilization of by-products," "a pattern data processing system," "a jet engine for aircraft," etc., the computer and aircraft industries have established a technological basis which have given them international standing. Contributions have also been made to the technical side of solutions to social problems such as water shortages, resource recovery, etc.

During this 20-year period the strength of technical development improved in the private sector, the substance of the technology required by industry changed, and there was a great shift in the need for Japanese-initiated technical development. In this sense the big project system was a turning point.

However, the special characteristics of the big project system are: 1) technical development either with competition, or with the cooperation and contribution brought about by the participation of researchers from multiple industries; 2) with the long-term view in mind, the active performance of research and development where the gestation period necessary for results is long; 3) the needs related to the accomplishment of technical development through the cooperation of multiple, dissimilar types of industry are thought to have become all the greater.

In the future it is clear that Japan's international role will become more and more important, and its world contribution to the field of industrial technology development can be expected to grow. Responding to these expectations, it will be necessary to assume world leadership in the development of industrial technology, and to attempt to concentrate the collective power of Japanese industry on the large-scale technical developments foreseen in rapid technological progress. For such technical development, the cooperation of various technical areas will be necessary and a systematic endeavor making active use of various types of systems will be required.

The big project system will be the central system which promotes such technical development and it is expected to play a role in indicating the direction that Japan's industrial technology will take. Because of this the system, which has passed its 20th year, will have to work for a rebirth so that it can meet the requirements of the new era. Specifically, the drive toward internationalization will become an important point.

This is an era that is ever demanding new things, and it is important that historical systems gradually reform in response to changes in society in areas like technical development where a long-term perspective is necessary.

Computer-Related Projects

Tokyo KOGYO GITJUTSU in Japanese Dec 85 pp 6-8

[Article by Kiyoshi Hasegawa, managing director, Applied Lighting Systems Technical Research Association: "Computers and Data Processing"]

[Text] 1. Background and Purposes of the Project

Between 1955 and 1965 computers came to be produced domestically, and there were various policies of government subsidies which culminated in the development of the world's first transistor computer at the Electrotechnical Laboratory. However, the advanced European and U.S. makers with their high technology started a serious assault on the Japanese computer market, and one after another, Japanese makers dealt with this by importing technology from the European and U.S. makers. However, in 1964 IBM, one of the world's largest companies, with approximately 80 percent of the world computer market, announced the epoch-making third generation computer System 360, the so-called series machine. It was an event so momentous that it would have completely banished existing computers from the market.

At this point the Japanese computer industry determined that the only way to survive was by extricating itself from following in the wake of foreign technology and developing independent technology which anticipated world technological advances. Because of this they devised a computer technology development plan which harnessed the technical development power of the entire country through the cooperation of government, universities, and the private sector. Proceeding from this as a national project came to be considered an urgent necessity. Accordingly, in 1966 the big project system was established and as its first project, "Research and Development of an Ultra-High Performance Electronic Computer" was inaugurated with the intention of developing the technology necessary to complete a large-scale commercial device which would meet standards applicable at an early 1970's international level and to do so using domestic technology.

As this project progressed, society rapidly became information-oriented, demand for computers increased greatly and the forms in which computers were used diversified remarkably. During these changes there was strong demand for computers suitable for processing the Japanese language which is a problem peculiar to Japan, and in addition for computers which could easily process characters, figures, objects, voice, etc., the so-called pattern data which were a weak point of computers up to that time. On the other hand, throughout the world there was vigorous basic research into pattern recognition and human intelligence, and pattern data processing technology was expected to play an important role in the new data processing systems of the 1980's. Accordingly, continuing the research and development of the ultra-high performance computer, "Research and Development of a Pattern Data Processing System" was inaugurated with the intent of developing the technology necessary for a new data processing system of the 1980's which could process pattern data.

2. Summary of the Projects

(1) The Ultra-High Performance Electronic Computer

A 5-year plan from 1966 to 1970 was announced, but midway it was extended a year and made into a 6-year plan because of things such as the use of buffer memories. Total R&D costs were originally estimated at Y12 billion, but since a portion of the research and development was shifted to the private sector, the governmental budget share was limited to approximately Y10 billion.

The target capabilities planned at the time of its inauguration were limited to: 1) development of IC for logic units; 2) possession of time-sharing system functions; 3) high reliability; 4) ease of use; 5) possession of a software system including management programs, word processing programs, etc. The concrete target capabilities followed estimations of world technology for 5 years after the time of system design and plans were made according to these. As a result, for the basic capabilities of the system mainframe, it was decided among other things that the average instruction time (Gibson mix) would be 200-300 nanoseconds, and that in order to build an easy-to-use system, they would develop output equipment such as Kanji display equipment, character recognition devices, voice output devices, figure processing equipment, etc.

(2) Pattern Data Processing System

An 8-year plan from 1971 to 1978 was inaugurated, but because the mode was changed from the initial centralized mode using large-scale control processing equipment to decentralized processing using personal, small-scale machines, this was extended 2 years and made into a 10-year plan. Total R&D costs were originally estimated at Y36 billion, but was limited to Y22 billion due, among other things, to the shift in system configuration from centralized to decentralized mode and to the cost reduction of IC's which then had a greater relative importance as components.

The announced target capabilities were: 1) the ability to directly input, recognize, store, process operations on, and output characters, figures, objects, voice, etc.; 2) the ability to process basic sentences; 3) the ability to process pattern data at a practical speed.

3. Project Results

(1) The Ultra-High Performance Electronic Computer

The largest configuration and capabilities of the experimental system are given in the table [not reproduced].

The average instruction execution time which is a basic system capability was very advanced, about 7 times as fast as the IBM System 360 Model 65 which was representative of large-scale computers at the time, and 1.5 times as fast as the System 370 large-scale Model 165 which appeared in the 1970's. Moreover, the efficiencies of the buffer memory system, virtual memory system, pipeline

con'rol system, etc., were very high and later standard large-scale machines came to follow these systems.

Its high-speed capability of less than 1.2 nanosecond delay time per logic IC gate was the highest for recording in the world at that time. Moreover, the MOSIC [metal oxide semiconductor field-effect-transistor] memory was developed as a buffer memory, but at that time semiconductor memory design had not been introduced anywhere in the world and it is significant that at this time the MOSIC memory has become the leading principal memory device.

The recording density of its magnetic disk was about four times that of IBM's best machine at the time and it could hold its own against IBM's leading magnetic disks of the 1970's.

The results of this research played a great role in improving computer technology while leading to 120 patents ano great amounts of know-how.

(2) Pattern Data Processing System

Figure 1 shows the experimentally developed integrated system prototype configuration. It is a decentralized processing system which joins seven new data processing special-purpose machines utilizing microprocessing technology with a polyprocessor and six world state-of-the-art pattern recognition systems which recognize characters, figures, objects, voices, etc. These machines are joined by a high-speed ring bus system using phototransmission technology. Differing from existing methods where computation and decision-making are brought about by feeding data into the computer by hand, it incorporates many new, futuristic technologies enabling it automatically to accept pictures and sounds as they are, like eyes and ears do, and then to recognize their respective meanings.

In regards to the development of devices and materials for inclusion in the system, one may cite many results like a semiconductor laser, photo-data processing components such as space modulation components, a magnetic bubble memory, semiconductor LSI, etc.

The results of this research have led to 494 patents, opened new markets through their application, and made a great contribution to the computer and related industries.

4. Dissemination of Results

Since completion of research and development, both projects have developed many basic, futuristic technologies, opened new markets and made great contributions to industrial development. In consideration they were given the 2nd and 10th Prime Minister's Prizes in the Japanese Industrial Technology Awards under the sponsorship of the Nikkan Shimbun Co. In 1985 the U.S. Department of Commerce investigated the condition of Japanese computer science and they reported that Japanese computer and data processing technologies were completely on a par with the United States in computer hardware technology and pattern data processing technology. This may be called proof

from both within and without the country of how great a contribution the results of these project developments have had in the expansion of today's Japanese computer and related industries.

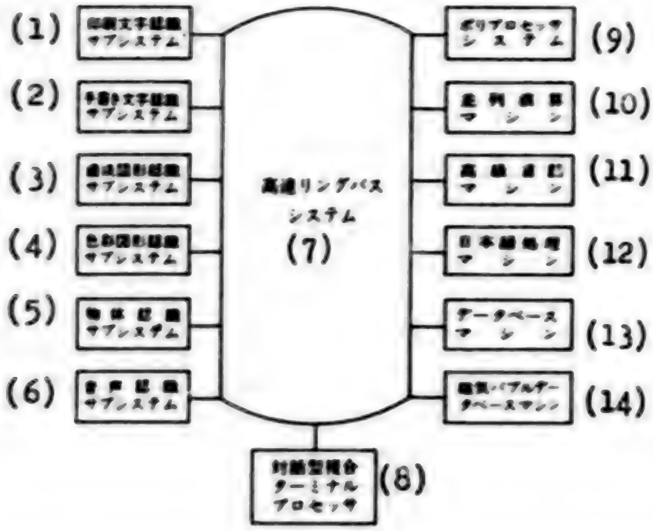


Figure 1. Pattern Data Processing System, Integrated System Prototype Configuration

Key:

1. Printed character recognition subsystem
2. Hand-written character recognition subsystem
3. Light and shade figure recognition subsystem
4. Color figure recognition subsystem
5. Object recognition subsystem
6. Voice recognition subsystem
7. High-speed ring bus system
8. Speech-type composite terminal processor
9. Polyprocessor system
10. Parallel operation machine
11. High-grade word machine
12. Japanese language processing machine
13. Data base machine
14. Magnetic bubble data base machine

Domestic makers have completely caught up in the principal technology of the early 1970's at which the research and development of the ultra-high performance electronic computer was targeted, and even against the large-scale machine which IBM announced in 1980, they now have the strength to cope by themselves. They have produced our present-day Japanese hardware technology.

The technology related to IC's such as logic circuit LSI, MOS memory, etc., was the key to the development of pattern data processing systems and the development of such logic LSI and large-capacity IC memories advanced it even further. These were combined, a 16-bit microcomputer was produced

experimentally, and it demonstrated its influence when incorporated in an integrated system prototype polyprocessor or LISP [list processor] machine. It became a pioneer in today's microprocessor and microcomputer boom.

The input and output devices in the character recognition equipment developed during the research and development of the ultra-high capability electronic computer were the key to the research and development of the pattern data processing system. They expanded in the development of the various character, figure, object and voice recognition systems which constituted the integrated system prototype and they built today's OA (office automation) and FA (factory automation) era. The integrated system prototype was made up of a number of special-purpose machines in a decentralized processing system joined by ring bus using photo-transmission technology. This system became the original form of today's LAN (local area network system) and has been widely introduced throughout society.

The results of these two projects became the basic technology of the rapid progress that followed and made possible the super LSI project, the photo big project, the supercomputer big project, the fifth-generation computer project, etc. They still play a large role as the motive force behind further future developments in these areas.

Jet Engine Projects

Tokyo KOGYO GIJUTSU in Japanese Dec 85 pp 9-12

[Article by Seiji Iwata, head of the planning department, Nisso Master Builders Col, Ltd.: "A Jet Engine for Aircraft Use"]

[Text] 1. Introduction

The development of a jet engine for civilian aircraft in the 150-seat class has recently moved forward through the cooperative international efforts of five countries including Japan. The engine will utilize the very latest world technology, raise fuel consumption efficiency to its limits, and demonstrate high performance, low noise, and low pollution. The development project is for the engine, the V2500, to be incorporated in the very latest aircraft in the 150-seat class which is expected to receive formal approval in 1988. Demand is expected to be high, and orders have already been received from European and U.S. airlines. The day is not so very far away when it will be seen flying around the world.

The Japanese engine industry, which has lagged behind in world standards, moved to take its place in the development of this newest engine by joining the international cooperative development as an equal partner with other engine makers. There are few engine makers even in the developed countries of the world, because of the technical difficulties, the size of the risk, etc.

Meanwhile, the first domestically produced low-noise fan-jet STOL [short take-off and landing plane], the experimental "Asuka," whose development has been directed by the Science and Technology Agency, is already undergoing flight

testing and the various types of tests now being performed should give Japan the world leadership in the development of future STOL transport aircraft. It will enable the use of jets at local airports where they can land and take off in short distances, and besides, because they land and take off at a steep angle, the area affected by the noise is reduced to one-tenth. The jet engine incorporated in this STOL craft is 100 percent domestically produced, developed under the big project system of the Agency of Industrial Science and Technology in the Ministry of International Trade and Industry.

These two projects demonstrate that the Japanese jet engine development level has reached current world standards. The jet engine industry is highly information-intensive, with the additional value of having accumulated the latest technology in various fields. It not only has a wide range of technical spin-off industries and strengthens our high-tech industrial foundation, but its significance has been really great in contributing to a true internationalization of Japanese industry, and it should play an important role in advancing the technological rebuilding of Japan.

The technology forming the basis of Japan's jet engine industry has been built up with great effort over many years with people involved in industry, education, and government acting together in the development project of the "FJR 710" jet engine used in the aircraft developed by the big project system of the Ministry of International Trade and Industry's Agency of Industrial Science and technology.

It was very timely that this aircraft jet engine was taken on in 1971 as a subject for development under the big project system, which was itself started in 1966. If we had not been able to participate in the V2500 project which has been called a unique opportunity in this era, then the Japanese engine industry might have lost an opportunity to be well regarded in the world in that area where advance has been rapid.

I would like to relate the results, particulars, etc., of the development of the FJR 710 aircraft jet engine and of the big project system which has played such an important role.

2. The "FJR 710" Big Project

Having been prohibited from all aircraft research and development for 7 years after the war, Japan lagged far behind world technical standards and even after reconstruction managed only the development of a small-scale turbojet engine. During this time world engine technology passed from turbojet to high bypass fan jet engines, and, one by one, fan jet engines were put to use in large-scale jet aircraft, and this technical gap kept widening.

Because of this in 1971 Japan planned the establishment of independent technology in the aircraft industry, especially in the aircraft engine industry. So they began the development of a high bypass fan jet engine under the big project system by targeting areas where future demand was expected while watching the activities of other countries at that time.

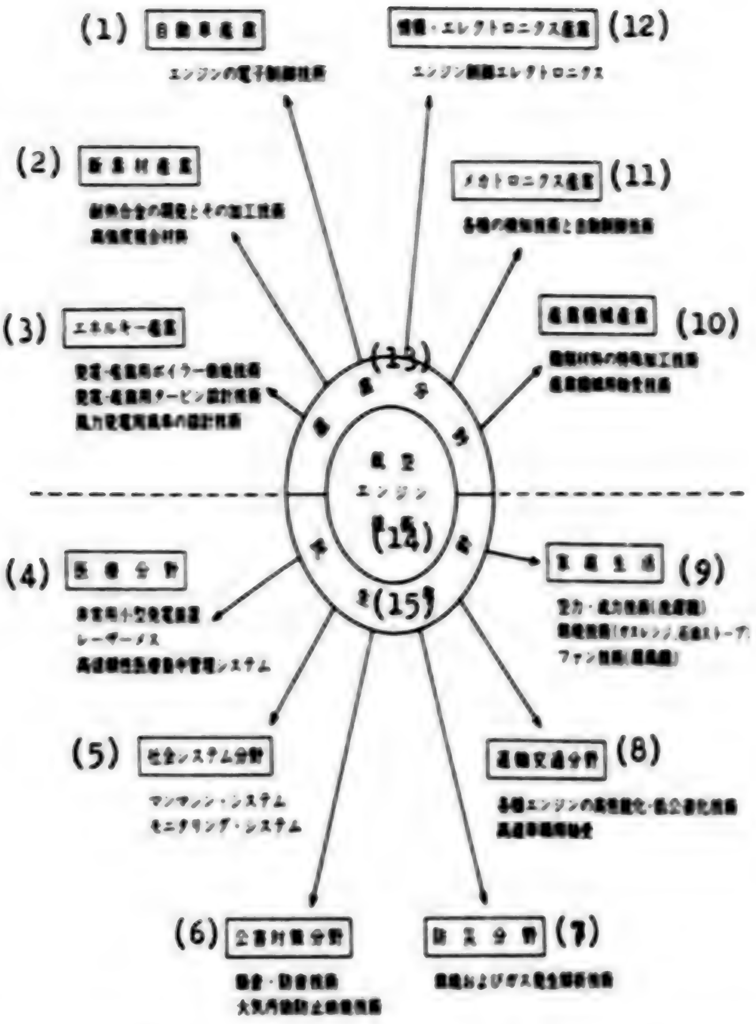


Figure 1. Ripple Effects of Aircraft Engine Technology

Key:

1. Automotive industry
2. Production of new materials
   The development of heat-resistant alloys and the technology of their manufacture; high strength composite materials
3. Energy production
   Boiler combustion technology for industry and electrical generation; turbine design technology for industry and electrical generation; design technology for windmills used for electrical generation
4. Medical field
   Small-scale electrical generation equipment; laser scalpels; highly reliable central medical management system
5. Area of social systems
   Man-machine systems; monitoring systems
6. Area of pollution countermeasures
   Noise and noise prevention technology; combustion technology preventing atmospheric pollution

[Key continued on following page]

7. Area of disaster prevention
   Analysis technology in combustion and gas generation
8. Areas of transportation and traffic
   High-performance, low-pollution technology; bearings for high-speed vehicles
9. Family living
   Air, water power technology (washing machines); combustion technology (gas ranges, oil stoves); fan technology (fans)
10. Production machinery industry
   Special treatment technology for difficult-to-machine materials; bearing technology for production machinery
11. Mechatronics industry
   Various intelligence-testing techniques and automatic control technology
12. Information-electronics industry
   Engine control electronics
13. Industrial areas
14. Aircraft engine technology
15. Public welfare areas

The project, called FJR 710, established as its goal the development of a high-performance fan jet engine which could endure frequent landings and takeoffs as a civilian aircraft, whose flight time was highly economical, and also whose atmospheric noise and exhaust pollution was minimal. The project was divided into a first stage program (1971-75) which stressed research into the trial production of the engine and into a second stage program (1976-82) which stressed research into engine operation. The timeframe for development was 12 years and total development expenditures of about Y20 billion were allocated.

Centering around the research and development offices in the Agency of Industrial Science and Technology, the Science and Technology Agency's National Aerospace Laboratory and the Aircraft Jet Engine Technology Research Association (members: IHI, KHI, and MHI) took charge in their respective areas and an effective drive for research and development was planned by actively seeking the opinions of well-informed people in academic and industrial circles on the Jet Engine Subcommittee of the Large-Scale Research and Development Sectional Meeting of the Industrial Techniques Council (subcommittee chairman: Keizo Hatta, former committee chairman of the Aviation Accident Committee).

During research and development, the trial production of the engine was carried out by investigating the principal components which make up the engine, such as the front fan, compressor, combuster, turbine, auxiliaries, noise absorption nozzle, etc., while at the same time completing overall performance tests concerning noise, exhaust, and safety against wind gusts, turbulence, crosswinds, etc. Then, operational testing was performed for many thousands of hours in order to confirm the performance, capabilities, durability, environmental adaptability, etc., of the trial engine.

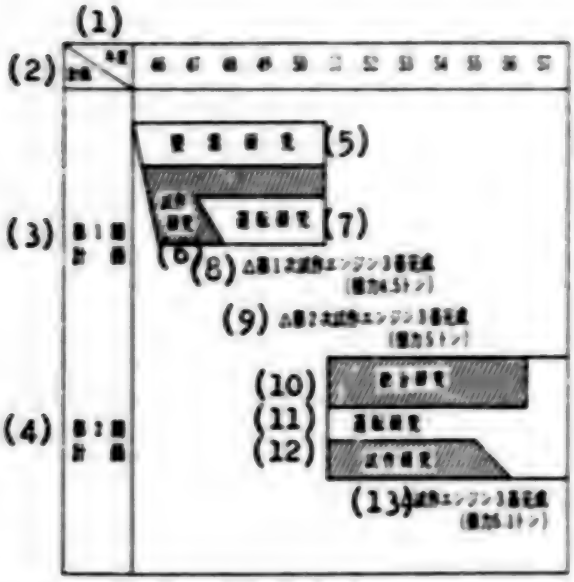


Figure 2. Research and Development Schedule

Key:
1. Year [Note: Add 25 to obtain Western calendar year]
2. Project
3. First stage program
4. Second stage program
5. Elementary research
6. Research into trial production
7. Operational research
8. Three first-order experimental engines completed (thrust: 4.5 tons)
9. Three second-order experimental engines completed (thrust: 5 tons)
10. General research
11. Operational research
12. Research into trial production
13. Three experimental engines completed (thrust: 5.1 tons)

As to the results, the first stage program was successful in the trial production of Japan's first fan jet engine for aircraft using independent technology. Moreover, based on these results, they were successful in the trial production of the second stage program's high performance engine which aimed for low noise, clean exhaust, overall efficiency, reliability, improved outfitting, and furthermore a reduction in weight that challenged design limits. As a result of operational testing covering many thousands of hours, expected capabilities were confirmed, and development was completed for a high performance fan jet engine which could endure frequent takeoffs and landings, whose flight time was economical, and further whose atmospheric noise and exhaust pollution were slight.

3. Research and Development Points

Due to the 12-year-long cooperation of industrial and academic authorities, we established a technology level in both hardware and software that is not inferior to that of the world's nations advanced in engine development. The approximately Y20 billion used in development is a small amount when compared to the approximately Y200 billion used to develop simultaneously a 10-ton-class engine in Europe and America. It can be called a research plan whose return on investment was excellent.

The efforts of the people involved were extraordinary during the development period and although subjects for conversation were not lacking, one of the biggest was the high altitude performance tests performed overseas. In order to perform tests on the ground concerning the performance of an engine in an aircraft flying at high altitude, a large-scale high-altitude performance test facility which recreates such conditions is necessary. However, there are none in Japan, so the tests were performed by borrowing equipment from Great Britain's National Gas Turbine Research Center. Three tests were performed over a number of years and the FJR 710's performance was confirmed by executing large-scale tests through the combined efforts of researchers, technicians and operators whose language and customs differed. This became the beginning of British-Japanese international cooperative development and also of the international cooperative development of the V2500.

Furthermore, the direct results of the development were many; abundant data regarding the various types of tests were collected (even the collection of erroneous data can be priceless); it became possible to make products of difficult-to-process materials with precision on the order of a micron, using various new processing techniques such as precision casting; it was possible successfully to use special materials and various nickel- and cobalt-base super heat-resistant alloys; various measuring techniques and measuring devices with excellent response were developed and established; highly reliable measuring methods were established in the control system technology, the composition analysis technology, and the air technology of the various engine-related fields, including fields where there were originally almost no data at all. In achieving these many results, a great contribution was made to the increased performance of various types of production machinery and plant operations. It was also useful in encouraging expanded areas of production in electronic products, screws, gears, bolts, tubes, etc.

Furthermore, even more important was the fact that with the accumulation of know-how and with the learning that passed between the many excellent researchers and technicians, we were able both materially and spiritually to build the foundation for our aircraft engine industry. This may certainly be called a project which fully demonstrated the special characteristics of the big project system.

4. Conclusion

Although this project required a long-term development period of 12 years, this period covered not only obtaining the above-mentioned results, but also the emergence of other new projects and systems. One of these is the high-efficiency gas turbine project of the Energy Conservation Research and Development System's "Moonlight Plan," begun in 1978. In light of the development of jet engine technology, possibilities were great for the development of a large-scale industrial gas turbine project, and it was started with energy conservation needs in mind. One opportunity which presented itself during this project was the development of materials such as fine-cell mixes and heat resistant alloys and this produced a need for even more fundamental technical development, and thus led to the start of the Next Generation Industry Basic Technology Research and Development System.

Although research and development projects which extend over long periods of time are apt to affect, along the way, the morale of the people involved, on this project the reason why successful accomplishment produced results is that intermediate targets were each announced, the full abilities of the people involved were drawn upon, and an atmosphere was present where it was possible to tackle problems as a group. Moreover, from here on things have been favorable from the standpoint of public finance, and although the budgetary framework was painfully tight, action was taken under relatively favorable conditions.

The big project system differs in its way of taking on subjects for development in response to the needs of this era, its way of dealing with development and its way of making progress. As an economic society advances, its technical development also advances and becomes more complex. The making of plans and strategies for technical development becomes more important and it becomes necessary to develop new methods of managing research. In regards to large-scale industrial science and technology which cannot be performed in the private sector, and which from the standpoint of the public economy, are considered important and even necessary in times of crisis, it will be necessary to utilize this system and furthermore to energetically stimulate research and development, actively to introduce strategy-making, planning and the development of new management methods which will become increasingly necessary in this, and to build up the basic physical strength of Japan as a technologically rebuilt nation. It is thought that the role of the big project system in this will become more and more important in the future.

Compound Production Systems

Tokyo KOGYO GIJUTSU in Japanese Dec 85 pp 12-14

[Article by Arahyoe Fujii, professor, Department of Science and Engineering, Myojo University (head director, Applied Laser-Compound Production Systems Technical Research Association): "Compound Production Systems Using Ultra-High Performance Lasers"]

[Text] 1. Introduction

The main project was inaugurated in 1977 and 8 years of long-term research and development was carried out, ending in March of this year. In August of this year the evaluation report for the main project was approved by the evaluation subcommittee of the Large-Scale Technical Development Sectional Meeting of the Industrial Techniques Council.

In this article I will give both the particulars of development since project inauguration and a summary of its results.

2. Conditions Soon After the Start

The year 1973 will be remembered as the final stage in a period of advanced growth for Japanese industry, as an era with a bleak outlook for the future because of energy shocks originating in the Middle East, and as an era in which domestic industries put all their efforts into energy conservation and into economizing. In Japan with no natural resources it was an era in which thoughts were about growth through important primary products, processing them through domestic advanced technology, and then exporting them. Then there were structural reforms within the Ministry of International Trade and Industry and based on the ideas of the younger personnel at the Machinery and Information Industries Bureau, the Research Association for the Production of a Model Unmanned Machine Shop (popularly known as the MUM Research Association) was inaugurated. They worked at producing a model workerless factory of the 1980's by bringing experienced scholars from universities and the Mechanical Engineering Laboratory together with researchers from machine-tool-related industries. Although this research continued until right up to the year before the inauguration of this project, the hope of somehow producing the world's first unmanned factory using domestic technology burned brightly in the people involved. The Research and Development Office of the Agency of Industrial Science and Technology successfully included it in the budget under a proposal partially modifying the results of the Research Association and the big project, which is the subject of this article, was inaugurated as a new subject for study in 1977.

3. A Summary of the Project and Its Results

The basic plan had as its objective "the development of a compound production system which can produce machine component parts from metal materials for multigrade, small quantity production with flexibility, speed, and under a coherent system; and the establishment of the technology necessary for this."

Total research and development costs were ¥13.7 billion, the development period was 8 years and centering on the Research and Development Utilization Office of the Agency of Industrial Science and Technology the research and development was performed by the Applied Laser, Compound Production System Technology Research Association composed of 20 private industry companies and 3 research centers, the Mechanical Engineering Laboratory, the Electrotechnical Laboratory, and the Kyushu Institute of Technology's Test Center.

As for concrete details, the research was performed with the goal of not only producing small-quantity, multigrade machine component parts with both speed and flexibility under a coherent system from raw materials processing to product testing with technology central to factory automation, but also developing a compound production system which applied laser technology to the area of metals processing.

In order to achieve this goal, seven items of research were begun as subjects for development of the essential technology: raw material processing, machining, laser application, automatic assembly, automatic diagnosis, measurement control, and total system. The important points in the development goals of these essential techniques are as follows:

a) System measurement and control techniques which compound and intensify the processes of raw materials processing, machining, automatic assembly, heat treating, and testing;

b) Techniques in which the various machining processes are performed by machining equipment incorporating interchangeable component parts;

c) Techniques in which diverse raw materials processing is performed by process machinery using a combination of metal patterns, rolls, etc.;

d) Techniques in which various assembly and conveying operations are performed automatically;

e) Techniques in which lasers are applied to measurement for cutting, welding, and heat treating;

f) Techniques in which accuracy compensation and breakdown predictions are performed by automatically diagnosing the operating condition of the entire system;

g) Measurement and production control techniques for efficient production;

h) Research and development was begun under a plan in which the abovementioned essential techniques were put together, an experimental compound production system test plant was constructed, general operating tests were performed and the results reflected in the design and construction of a system which was expected to be put to actual use shortly thereafter.

Development on these essential technical research items moved forward based on close liaison between the national research agencies and the companies in charge, and the initial goals were accomplished in 4 years (1980).

In 1981 design and construction were begun on the equipment to be brought to the Tsukuba test plant, in the middle of November 1983 moving-in was begun pending completion of the building and in the same year installation of all equipment was completed.

The layout of the Tsukuba test plant is shown in Figure 1 [not reproduced] and system organization and product flow is shown in Figure 2.

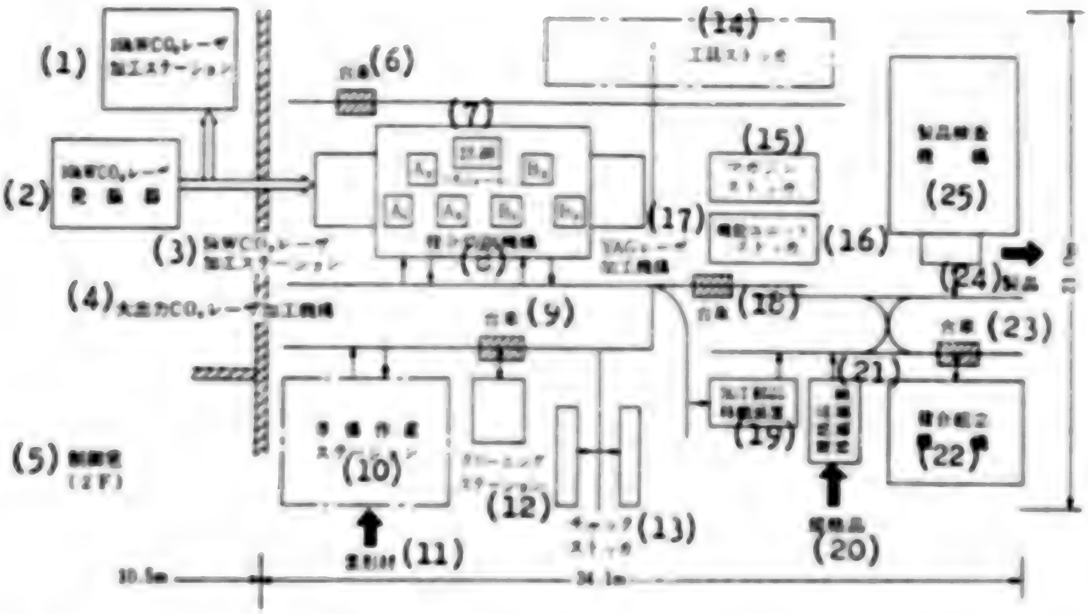


Figure 2. System Organization and Product Flow in the Experimental Plant

Key:

1. 10 kW CO_2 laser processing station
2. 10 kW CO_2 laser oscillator
3. 5 kW CO_2 laser processing station
4. High output CO_2 laser process machinery
5. Control room (2F)
6. Vehicle
7. Measurement (Module)
8. Compound machining mechanism
9. Vehicle
10. Preparation station
11. Raw materials
12. Cleaning station
13. Chuck stocker
14. Tool stocker
15. Magazine stocker
16. Functional unit stocker
17. YAG laser processing mechanism
18. Vehicle
19. Processed parts transfer equipment
20. Standardized goods
21. Standardized goods transfer equipment
22. Compound assembly mechanism
23. Vehicle
24. Product
25. Product testing mechanism

Through October of 1984, the last year of the project, the various machines were operated individually; the compound cutting machinery, compound assembly machinery, the product testing machinery, and the laser processing machinery subsystems. After verification of their performance, general operation of the

total system was begun starting in November of that year. The system was in continuous operation for 115 hours from the end of February to the beginning of March 1985, the overall operating performance of the system was confirmed, and all testing was completed without mishap.

The overall system operation results were confirmed as follows:

1) Production Characteristics

As a result of mixed production of three products as output (main axle heads, 2-axle gear boxes, and 3-axle gear boxes), it was confirmed that for products requiring about 1 month of production time at existing machine shops, a net 1.5 production days could be saved for three products.

2) Flexibility, Speed, and Reliability

With compound cutting machinery with automatic chuck and unit exchange, it was possible to process simultaneously different types of rounded and cornered products, and with compound assembly machinery it was possible to assemble parts with complex shapes accurately in 1 hour with the automatic exchange of cassettes and grasping tools. Moreover, the control equipment accompanying these was easily able to cope with production schedule changes under a system of decentralized level structure. Furthermore, system reliability was confirmed through on-line measurement, as was high-precision high-speed processing using laser processing compounded with other operations (a CO_2 10 kW laser for welding and surface treatment, and YAG 300 W laser for burr and chip treatment). The actual-use performance of the 20 kW CO_2 laser processing equipment which could not be moved into the Tsukuba plant and four types of raw materials processing equipment were verified in a separate plant.

4. Conclusion

During the principal research and development, the world's first large-scale new factory automation experiment was completed through the cooperation of researchers in government, education, and the private sector. The number of foreign observers at the Tsukuba test plant has exceeded 1,500 and it has had great international influence. Applications for patents and utility models have exceeded 200 and over 500 research papers have appeared in academic circles and elsewhere. Furthermore, by the end of the project there were seven reexecution contracts and treasury receipts have amounted to Y480,000. The above-mentioned results have earned special mention even among the other already completed big projects. Lastly, I wish to end this article by expressing my deep gratitude to the appropriate people involved in the project.

Resource Recovery

Tokyo KOGYO GIJUTSU in Japanese Dec 85 pp 15-17

[Article by Yukie Awaya, chairman of the board, Clean Japan Center: "A Technical System for Resource Recycling"]

[Text] 1. Introduction

Up until now, if one mentioned refuse management, the response was most likely to be landfill and incineration. However, because of the difficulty of maintaining the ultimate disposal areas, the increase in substances which are difficult to incinerate, environmental and pollution problems, and also because of the increased concerns about the efficient use of resources, concerns made opportune by the so-called oil crisis, wider attention has been given to management methods which treat refuse as a resource.

In response to such social concerns the Ministry of International Trade and Industry's Agency for Industrial Science and Technology undertook the research and development of technology for making refuse a resource. This research and development was "a technical system for resource recycling" whose purpose was the harmonizing of urban refuse management and the use of resource reclamation. The project was named "Stardust '80," incorporating the hope that urban refuse reclamation technology would be the bright star of the 1980's.

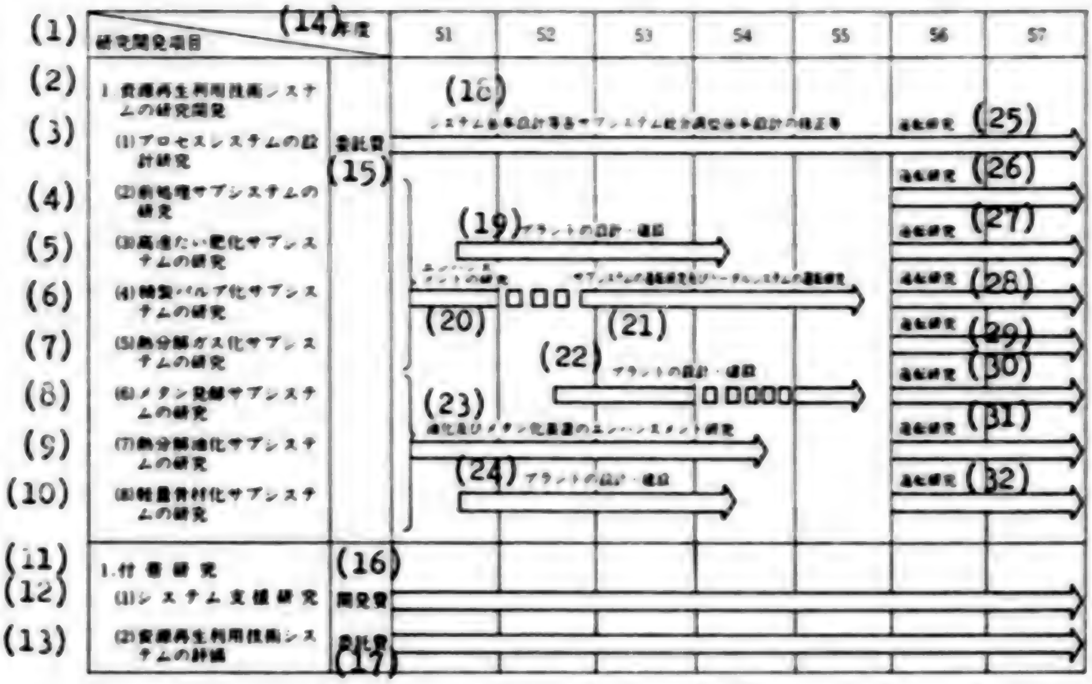
2. Summary of the Project

When the Stardust '80 Plan was started in 1972, the Agency for Industrial Science and Technology prepared an investigation of foreign and domestic technology and completed a written request "for the solution to one city's refuse problem in regards to the research and development of a technical system for resource recycling." Later the 3-year period from 1972 to 1975 was made the first stage of the project and research and development were performed on the essential technology. The principal intent of the research and development during this period was an investigation of a total system of urban solid waste management with an eye toward the use of resource recovery. They performed: 1) a feasibility study on the innovative essential techniques necessary to structure the system, together with 2) the developmental planning for a total system having the optimum combination of these various essential techniques. Next, starting in 1976, as the second stage of the project they established a technical system prototype and performed demonstration tests at a large-scale pilot plant, following the schedule in Table 1.

The main system is made up of the following subsystems:

1) A pretreatment subsystem based on semi-damp selecting, pulverizing, and classifying equipment which separates the mixed refuse into three main piles: a garbage pile, a paper pile, and a plastic pile.

Table 1. Research and Development Schedule for the Technical System for Resource Recycling



Key:

1. Research schedule
2. 1. R&D for the technical system for resource recycling
3. (1) Design research for the process system
4. (2) Research on the pretreatment subsystem
5. (3) Research on the high-speed compost subsystem
6. (4) Research on the refined pulp subsystem
7. (5) Research on the pyrolysis gas recovery subsystem
8. (6) Research on the methane fermentation subsystem
9. (7) Research on the pyrolysis oil recovery subsystem
10. (8) Research on the light-weight aggregates subsystem
11. 1. Incidental research
12. (1) System support research
13. (2) Evaluation on the technical system for resource recycling
14. Year [Note: Add 25 to obtain Western calendar year]
15. Consignment expenses
16. Development expenses
17. Consignment expenses
18. Basic system design and modification of the basic overall control design of the various subsystems
19. Plant design and modification
20. Enhancement research
21. Operational research on the subsystems and on the total system
22. Plant design and construction
23. Enhancement research on the oil and methane generation equipment
24. Plant design and construction

25-32. Operational research

2) A high-speed compost subsystem which composts the separated garbage pile.

3) A refined pulp subsystem which turns the separated paper pile into pulp.

4) A pyrolysis gas recovery subsystem which turns the separated plastic pile into fuel gas.

5) A methane fermentation subsystem which turns garbage into methane gas.

6) A pyrolysis oil recovery subsystem which turns paper and plastics into fuel oil.

7) A light-weight aggregates subsubsystem which produces aggregates from the inorganic residue from the other subsystems.

These subsystems together have the versatility to enable the building of new treatment systems by combining them with existing treatment methods like landfill, incineration, etc.

Table 2. Organizations Performing Research and Development

Research Schedule	Research Organizations or Consignees
1. R&D for the Technical System for Resource Recycling	
(1) Design research for the process system	Ebara Corporation Uchida Machinery Daishowa Paper Mfg. Co. Daishowa Engineering Japan Steel Works Hitachi, Ltd. Hitachi Plant Engineering and Construction Co. Tokyoto Kankyo Seibi Co. Babcock-Hitachi
(2) Research on pretreatment subsystem	Ebara Corporation
(3) Research on high-speed composting subsystem	Hitachi Ltd.
(4) Research on refuned pulp subsystem	Uchida Machinery Daishowa Paper Mfg. Co. Daishowa Engineering
(5) Research on pyrolysis gas recovery subsystem	Ebara Corporation
(6) Research on methane fermentation subsystem	Hitachi, Ltd. Hitachi Plant Engineering and Construction Co.

Research Schedule	Research Organizations or Consignees
(7) Research on pyrolysis oil recovery subsystem	Hitachi, Ltd. Babcock-Hitachi Tokyoto Kankyo Seibi Co.
2. Incidental Research	
(1) System support research	Chemical Technology Research Center National Research Institute for Pollution and Resources Hokkaido Industrial Development Test Center Shikoku Industrial Development Test Center
(2) Evaluation on the technical system for resource recycling	Japan Industrial Technology Promotion Association

A summary of the system is given in Figure 1.

Figure 1

1) It would comprehensively and effectively perform necessary treatment while creating resources, reducing pollution, etc.

2) It would enable the reclamation of energy material resources from the appropriate parts of the waste being treated.

3) It would satisfy the requirement that it not pollute in order to preserve the environment.

4) It would be very safe and maintenance supervision would be relatively easy.

5) Treatment costs would be favorable compared to present treatment methods when the secondary results from recycling are considered.

6) It would be highly suitable to our social system.

Experimental research was performed following these development goals, and with the many research results produced, any number of these techniques have already been put in actual operation in towns, cities, and villages. Moreover, a special characteristic of the project is that the whole system is, of course, a combination of the individual essential technologies and that it has the versatility to enable the building of new treatment systems through combination with existing treatment methods like landfill, incineration, etc. In order that the results be spread widely, the Clean Japan Center Foundation has recently been working on their wide dissemination within Japan of course, but also overseas. As already mentioned, refuse treatment systems have new increased options as to how they recover resources and diverse systems satisfying the special characteristics of localities are required. With this in mind, it is hoped that the results of the Sta dust 80 system will be spread even further in the future.

The pretreatment subsystem has already been introduced at six locations such as Takigawa City in Hokkaido, and Geisei Village in Kochi Prefecture. Furthermore, the high-speed composting subsystem has been put in operation at 14 locations in Japan, including Takigawa where it is used in combination with the pretreatment subsystem. Results have also been achieved by using a wind-driven separator, etc. In addition, overseas, the pretreatment subsystem technology has been provided to Australian private-sector iron-working machinery makers, and there have been requests for technical assistance from the Philippines, Sri Lanka, Mexico, etc. At the Clean Japan Center Foundation we have worked to spread a presentation of the system that is positive in terms of practical use, first to autonomous groups and makers with n Japan, and to various organizations overseas. We have also responded to various inquiries on a number of aspects.

Fresh Water From Sea Water

Tokyo KOGYO GIJUTSU in Japanese Dec 85 pp 17-18

[Article by Yochio Murayama, ordinary director, Water Production Promotion Center: "Research and Development on the Desalinization of Sea Water and the Utilization of By-Products"]

[Text] 1. Background on the Research and Development

Water is an important substance essential to the existence of human beings and its use may be divided into these categories: water for agriculture water for human consumption, and water for industry. Up to now, the amount of water used in Japan has increased along with the development of the Japanese economy and society. Although the amount of water used for agriculture has only increased slightly, the amounts for human consumption and industry has increased rapidly due to the tremendous growth of the Japanese economy since 1955. Because of water supply and demand estimations made in 1967, large water shortages were feared by 1985 in various areas such as southern Kanto, northern Kyushu, and Kinki seaside regions. In order to deal with the water shortages predicted for the near future, the Ministry of International Trade and Industry adopted "The Desalinization of Sea Water and the

Utilization of the By-Products" as one of its big projects and thus the research and development was carried forward.

2. A Summary of the Main Project

The Agency of Industrial Science and Technology which was in charge of the research and development made a detailed investigation of various desalinization methods. As a result, the conclusion was reached that the most suitable method was the long-tube, multistage flash evaporation method with pH adjustment by adding acid as a pretreatment of the sea water to prevent the growth of scale. The principal goals of the research and development were the following three points:

1) The establishment of the technology to design a desalinization plant capable of producing 100,000 cubic meters or more of fresh water per day.

2) Lowering desalinization costs by decreasing equipment construction costs, and by raising heat efficiency.

3) The explanation of conditions under which trouble-free safe operation could be performed.

3. Results of the Main Project

As a result of this research and development, the various techniques listed below were developed. Japanese sea water desalinization technology using evaporation reached the world's highest standards.

1) Design, construction, and operation techniques were established for a large-scale plant capable of 100,000 m^3/day, even though at the time of project inception only desalinization plants capable of 10,000 m^3/day had ever been built.

2) Construction technology was established for the world's first ferroconcrete evaporation boiler and we achieved an epoch-making scaling-up of plant size, a decrease in construction costs for large-scale plants, and a tremendous improvement in corrosion resistance.

3) The flow speed of the sea water to be treated in the evaporation boiler (brine) was increased to more than twice that of existing plants and thus construction costs were reduced by making the boiler more compact.

4) Production techniques were established for long-tube type plants which have advantages on a large scale. By using long tubes, the flow resistance of the sea water supply was reduced, thereby lowering operating power costs.

5) By improving pretreatment techniques such as gas and carbonic acid removal, it was possible to increase the temperature of the sea water to 120°C which is close to its hard scale deposition limit. In this way the heat efficiency of the fresh water plant was greatly improved. Moreover, these improved pretreatment techniques were not only effective in preventing

corrosion in the plant constru tion materials, but they also made possible the use of cheaper materials i. the heat transfer pipes.

6) Techniques were establish d to produce chlorine, caustic soda, and caustic potash from the concentrated discharge brine.

Especially noteworthy among the techniques developed by the main project was that of building the ferro-concrete evaporation boiler In a large-scale plant of more than 30,000 m^3/day, not only are construction costs lower than plants on a previous scale, but it has the added virtue of on-sit construction. However, a desalinization plant utilizing a ferro-concrete boiler has regrettably yet to be buil . Moreover, although 10 plants with long-tube systems have been built, most of the world's desalinization plants are still of the short-tube type.

This is because Middle Eastern countries where most of the demand for desalinization plants lies are skeptical of the large-scale plant technology developed by the big project and have been slow in proceeding in its application. This is because in their operational experiences over the past 30 years, right up to the present, they have waged a difficult battle against corrosion and scale deposition and also because they have had problems with the quality of their operating personnel. Another big reason for the skepticism of the Middle Eastern countries is the fact that a fresh water plant with a concrete boiler has yet to be used in Japan.

However, the designs, materials, and techniques for preventing corrosion and scale deposition developed by the big project have had great effect because of their broad application in short-tube type plants. Since the end of the big project, Japanese makers' market share has increased tremendously in the worldwide construction of multistage desalinization plants and this is likely a result of the big project.

4. Ripple Effects

Based on the results of the big project, there has been technical cooperation between Japan and the countries needing desalinization.

Starting in 1978 and continuing until 1979, the Water Production Promotion Center (foundation), commissioned by the cartel governments, performed a feasibility study on the construction of desalinization plants with concrete boilers using cement, steel, gravel and sand produced by the cartel countries.

Since 1979 the Group for International Cooperative Enterprise has collaborated technically concerning desalinization with the Government of Saudi Arabia. Because of various problems, this technical cooperation was slow in getting started, but has been on track since May 1984. A research center for desalinization technology has been organized, and plans continue for joint research.

In 1983 and 1984 with requirements received from the Algerian Government, the Group for International Cooperative Enterprise also commissioned the Water

Production Promotion Center to execute a feasibility study on the construction of 150,000 m^3/day, 150,000 m^3/day, and 60,000 m^3/day desalinization plants for the cities of Algiers, Oran, Mostaganem, respectively. Later the Water Production Promotion Center was commissioned directly by the Algerian Government to prepare bid specifications for the construction of desalinization plants in Algiers and Oran.

In regard to the Oran fresh water plant, international bidding by nomination is presently taking place and the deadline is January 1986. A number of Japanese companies are expected to have their bids accepted.

Furthermore, there are plans to construct a 180,000 m^3/day desalinization plant in Oman in conjunction with an electric power generating facility. In 1985 the Water Production Promotion Center was commissioned by the Group for International Cooperative Enterprise to perform a feasibility study in cooperation with the Electric Power Development Co. and the Nippon Plant Association.

13008/6091
CSO: 4306/3036

TRANSPORTATION

DEVELOPMENT OF HYDROGEN-FUELED CAR DISCUSSED

Tokyo JIDOSHA GIJUTSU in Japanese Feb 86 pp 232-236

[Article by Jun Hama, Yasuo Kawaguchi, and Yoshitada Uchida]

[Text] 1. Foreword

The authors have been conducting research on the experiment of a hydrogen gas engine with the goal of developing a power source for a vehicle with the use of hydrogen as fuel, which tops the list of substitute fuel for petroleum in the future. This time, we have attempted to develop an engine system with the use of Metal Hydride (abbreviated as MH) as the source of storing hydrogen. In order to run evaluation tests on this vehicular power source, it was loaded on a car. Following is the introduction of the characteristics and functions of the experimental car.

2. Structure and Characteristics of the Experimental Car

The outline of the functional device of the experimental car is shown in Chart 1. The engine system which was put in the experimental car consists of an engine, a fuel tank which uses MH for storing hydrogen (abbreviated as MH tank), an exhaust heat exchanger, a hydrogen gas decompressor, a hydrogen gas control device and an electronics control device, et al.

The form of storing hydrogen by MH adopted here is a method of occulsion and release of hydrogen with the use of a reversible reaction indicated by the following formula.(1)

Hydrogen occlusion alloy + Hydro gas
  occlusion (cooling, pressurization)
                                MH + heat
  release (heating, decompression)

This storage method has the following characteristics: it is easy to fill and release hydrogen gas; it is able to store hydrogen for a long period of time at room temperature and at atmospheric pressure. Although it still has the shortcoming of not being able to store much hydrogen per weight, it has the following merits compared with a hydrogen storage method with high pressure gas or liquid. The loss of energy while filling and storing is small; since it

does not require any special container strong enough to endure high pressure or a container for extremely low temperature. Therefore, this storage method has been researched as the preferred form for future storage and transportation of hydrogen

The principle of operation of the engine system when this hydrogen gas storage system is used, will be explained by the structure shown in Chart 1.

In the case of the filling of an MH tank with hydrogen gas, hydrogen gas should be supplied to an MH tank via a decompressor from the hydrogen supply facility outside the car. The pressure at the time of filling with gas varies depending on the type of MH, but it is largely around 10 or 20 atmospheres. At the time of filling, reactions forming MH will take place inside the tank, and heat will build up Therefore, the heat is removed by supplying cooling water for the MH tank from outside the car, and promoting hydrogen occlusion.

Next, in the case of filling the engine by releasing hydrogen gas, start by filling the engine with hydrogen released from MH and hydrogen gas stored in a gaseous state in the plenum within the MH tank via a decompressor. Next, using the exhaust gas as a heat source, make warm water with the exhaust heat exchanger. With this warm water as a heating medium, heat the MH, to create hydrogen gas, and maintain filling.

In this hydrogen supply system, change in the volume of hydrogen used will always occur prior to the development of hydrogen gas from MH. Therefore, the ability of the volume of the hydrogen developed from MH to react is an important factor in determining whether the system functions or not. Because the development of hydrogen gas is delayed and the hydrogen pressure cannot be maintained, it has been considered difficult to use a type of engine that directly injects hydrogen into a cylinder at the same time as the compression stroke, which is necessary to eliminate backfire and improve specific power. There is no example of putting this type of an engine on an experimental car using MH. (2)

From the very beginning of this research, the use of MH was assumed. The research has noted the supplying of low pressure hydrogen gas at a couple of atmospheres pressure in the study of a hydrogen supply system for the engine. From the experiment of single cylinder engine, it was recognized that the method of directly injecting hydrogen in the cylinder in the first half of a compression stroke is more effective in preventing abnormal combustion such as backfiring and the improvement of specific power and heat efficiency. Also a 4-cylinder high tension ignition engine with the use of this supply system could be developed by remodeling a gasoline engine and put on the market on an experimental basis. This research indicated that the engine could be used in a car with a limited range of practical use.(3) Next it made the hydrogen supply system of the MH system for the use of this experimental engine on an experimental basis. Then, the hydrogen supply system and the engine were actually connected, and bench tests were performed. Thus, it also proved that this experimental system functions as a MH engine system.(4)

This experimental car carried an inner cylinder propulsion-type engine system. It also has the characteristic of being loaded with an electronic control system

which measures, diagnoses and controls the entire system such as the control of engine power output, the control of hydrogen volume generated in the MH tank in order to improve the ability to drive, ability to control and safety, which are necessary for a power system of a vehicle. Consequently, the purpose of this experiment is to find out if these characteristics may fully function on an actual car.

3. Function and Specification of Each Part

3.1. Hydrogen gas engine (3)

The engine which was made on an experimental basis was a gasoline engine converted for the use of hydrogen. The structure of the cylinder head, the major remodeled part is shown in Chart 2, and its items are indicated in Table 1. The engine has two intake valves, one exhaust valve, and one hydrogen valve, four valves total per cylinder. A particularly, large hydrogen valve was slightly actuated so that it could inject the necessary amount of low pressure hydrogen gas needed in the first half of the compression stroke. The intake system has the first valve control device for cutting off air intake only when braking the engine and the second valve control for the promotion of mixing during low engine rpm and the improvement of torque (refer to Chart 4 which appears later). The experimental engine achieved 44 kW output rating at 4,500 rpm and maximum heat efficiency of 35 percent in the bench test.

3.2 Hydrogen occlusion alloy and tank

The specifications and the outline of the structure of an MH tank are shown in Table 2 and Chart 3. In order to improve the response of the nascent hydrogen volume to the hydrogen volume used for the engine, mesh metal allow was used for the occlusion alloy. In order to heat up this alloy evenly, fin-attached tube-type heat exchanger was equipped, and as it is shown in the chart, a war water outlet was made on both sides of the MH tank so that warm water will flow on opposite sides. The tank capacity to store the hydrogen gas is approximately [illegible] Nm^3. During nascent pressure, 3 kgf/cm^2G, approximately 70 Nm^3 can be used. In order to fill this much volume with hydrogen, it takes approximately [illegible] hours at the filling pressure of 25 kgf/cm^2G.

3.3. Exhaust heat exchanger

This is a device which creates the warm water necessary for heating MH with exhaust as a heat source. In order to set it up in the exhaust gas passage, it is devised so that it will experience minimal loss of pressure and at the same time it will be able to improve completely heat exchange efficiency. The exhaust exchanger is 184 mm wide, 900 mm long, and 110 mm deep. It is a jacket and tube shaped heat exchanger, and its surface area is approximately 0.9 m^2.

3.4. Hydrogen gas decompressor

It is a pressure governor device necessary for filling the MH tank with hydrogen gas and supplying hydrogen gas from the tank to engine. The device is equipped with filters for removing the MH particles and cut off valves for stopping the supply of hydrogen in case of an emergency (Chart 4).

3.5 Drive Control Device

This device consists of 1 chip 8 bit microcomputer and various sensors which are attached to the computer and actuators. It controls the engine output and the volume of hydrogen released from MH, and diagnoses abnormalities of each part of the system, so that the car is able to run smoothly and safely. The outline of these controls are shown in Chart 4. Following are detailed contents of the controls.

(1) Control of engine output

The hydrogen gas control device, the main body of the output control, consists of injection within the cylinder system which has direct coupling with the acceleration and premix system for smooth driving (driveability). These two systems can switch the supply passage by each driving mode which is determined by the position of accelerator and engine rpm. The premix system works at the time of low load driving including the time of starting and time of idling. In order to prevent abnormal combustion such as backfiring and after burning, the premix system was made in such a way that the supply of hydrogen would be stopped at the time of starting hydrogen supply after high tension ignition, at the time below cranking rpm, and at the time of braking the engine. On the other hand, injection within the cylinder system is equipped with limiters which regulate the maximum volume of hydrogen flow at each engine rpm.

(2) Control of hydrogen gas released from MH tank

The volume of hydrogen gas released takes the pressure inside the MH tank as a barometer. Its control is conducted according to the inner pressure of the tank by adjusting the heating value given to the MH. When the inner pressure of the tank drops below the set value, exhaust will be introduced to the exhaust heat exchanger. The release of hydrogen will be promoted by leading warm water made by the exchanger to the tank. Conversely, when the inner pressure goes up, try to bypass exhaust gas. Try not to heat the circulating water, and try to control the hydrogen from being released. In case the inner pressure of the tank drops below the set value under the driving condition in which the heat value of exhaust gas is not sufficient for heating MH, such as at the time of starting up the car, and at the time of idling, the mechanism of maintaining higher engine rpm than usual idling rpm (high idling for warming in MH tank) was equipped. In case the remaining volume of hydrogen in the tank drops, a control mechanism, which checks the water temperature of the MH tank outlet and allows water fo flow only to the radiator passage if necessary, and uses an electric fan to reduce temperature, and is equipped to prevent the MH from overheating and the circulating water from boiling.

Along with the conditions related to the content of the two controls above the engine rpm, the optimal ignition time against load, and critical values which judge the abnormality of the functions are set as a table on the data ROM of the electronic control device in advance. A reference table system, which reads out information when necessary, was adopted. Moreover, the electronic control is equipped with a display section by the LED which monitors barometer values repressing the functions of each part. This way, the values can be supervised from the driver's seat. In case anything is abnormal, a buzzer will report it.

4. Prediction of the Performance of the Experimental Car

These systems were put on a small 6-passenger car, whose length is approximately 4.7 meters, width is approximately 1.7 meters, and height is approximately 1.9 meters. The photograph [photo not reproduced] of the experimental car is shown in Chart 5. Emphasis was put on the convenience and safety of operation and measurement of each device rather than practicality when determing the position of these devices except those that were limited by the car body. The configuration is shown in Chart 6. Chart 7 indicates the predicted performance curve caclulated on the basis of performance of the engine and items on the car body. The car has the maximum speed of more than 100 km/h when driving on steady ground. When the volume of hydrogen necessary is converted from driving resistance from the time of 4th gear, 60 km/h of steady driving, over 200 km of driving can be expected with a full tank of hydrogen. This goal was achieved during a real driving test. Further improvement of performance and handling, and evaluation of this system as a means of moving will be conducted.

5. Conclusion

The performance and characteristics of this car having an engine system using Metal Hydrite as storage for hydrogen, are introduced in this paper. Although many factors still need further study, the content of the research performed up to the development of the experimental car is summarized as follows:

1. A gas engine whose type is injection within the cylinder, using MH as a storage source was developed by the remodeling of an existing engine.

2. The MH tank was made with special attention to the improvement of respondability. It was recognized that this tank is capable of handling the changes in the volume of hydrogen used for injection within cylinder type engine.

3. Driving control devices for the car to control both the engine and the tank were made, and these functions were proven.

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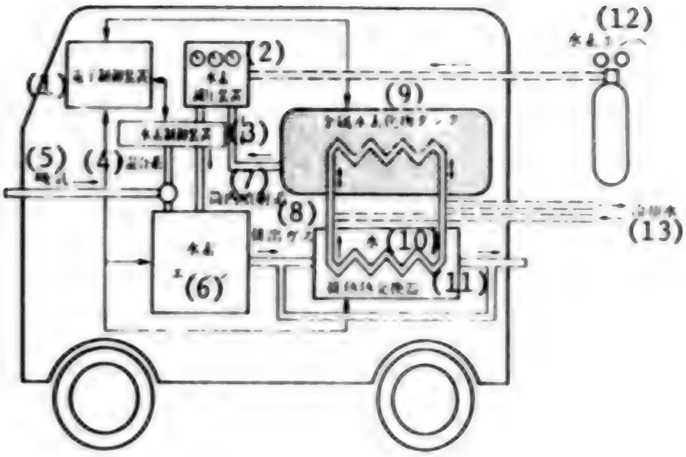


Chart 1. Structure of Hydrogen-fueled Car

Key:

(1) Electronic control device
(2) Hydrogen decompressor
(3) Hydrogen control device
(4) Premix system
(5) Air intake
(6) Hydrogen engine
(7) Inner cylinder propulsion system
(8) Exhaust gas
(9) Metal hydride tank
(10) Water
(11) Exhaust heat exchanger
(12) Hydrogen cylinder
(13) Cooling water

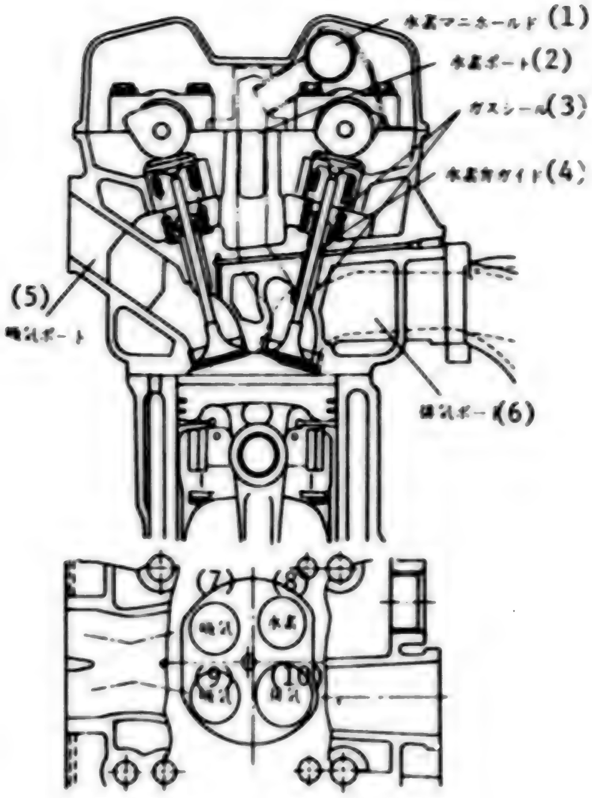


Chart 2. Outline of the experimental cylinder head

Key:
- (1) Hydrogen manifold
- (2) Hydrogen port
- (3) Gas seal
- (4) Hydrogen valve guide
- (5) Air intake port
- (6) Exhaust air port
- (7) Air intake
- (8) Hydrogen
- (9) Air intake
- (10) Exhaust air

(1)	[illegible]	[illegible]
(2)	[illegible]	[illegible]
(3)	[illegible]	88.5 × 80 mm
(4)	[illegible]	1968 cm^3
(5)	[illegible]	[illegible]
(6)	[illegible]	[illegible]
(7)	[illegible]	[illegible]
(8)	[illegible]	[illegible]
(9)	[illegible]	[illegible]

Table 1. Basic item of an engine

Key:

(1) Type, 4 cycle high tension ignition engine
(2) Configuration-Number of cylinders, series 4 cylinders
(3) Bore x Stroke, 88.5 x 80 mm
(4) Volume of exhaust air, 1968 cm^3
(5) Shape of combustion chamber, pent roof
(6) Organization of moving valve, DOHC
(7) System of intake air and exhaust air, cross flow
(8) Number of valves, 16, 6 (Intake 2, exhaust 1, hydro 1)/cylinder
(9) Hydrogen supply system, injection inside mechanically operated cylinder

(1)	[illegible]	[illegible] SUS [illegible]
(2)	[illegible]	320 × 2100 (2500) mm
(3)	[illegible]	1 [illegible]
(4)	[illegible]	[illegible] 140 l
(5)	[illegible]	(LR) $Ni_5Al_{0.1}$
(6)	[illegible]	480 kg ([illegible] 60 l)
(7)	[illegible]	183 kg
(8)	[illegible]	663 kg
(9)	[illegible]	30 kgf/cm^{2}G
(10)	[illegible]	[illegible]
(11)	[illegible]	21.5 m^2

Table 2. MH tank

Key:

(1) Type, all welded SUS steel made cylindrical type
(2) Diameter x length, 320 x 2100 (2500) mm
(3) Number of units, 1
(4) Capacity, approximately 140 1
(5) Occulsion alloy, (LR) $Ni_5Al_{0.1}$
(6) Volume of alloy filling, 480 kg (approximately 60 1)
(7) Weight of container, 183 kg
(8) Total weight, 663 kg
(9) Design pressure, 30 kgf/cm^{2}G
(10) Type of heat exchange, warm water heating style inner heat exchange type
(11) Surface area, 21.5 m^2

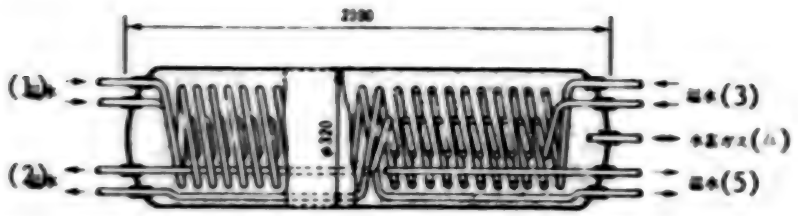


Chart 3. Outline of the structure of MH tank

Key:

(1) Warm water
(2) Warm water
(3) Warm water
(4) Hydrogen gas
(5) Warm water

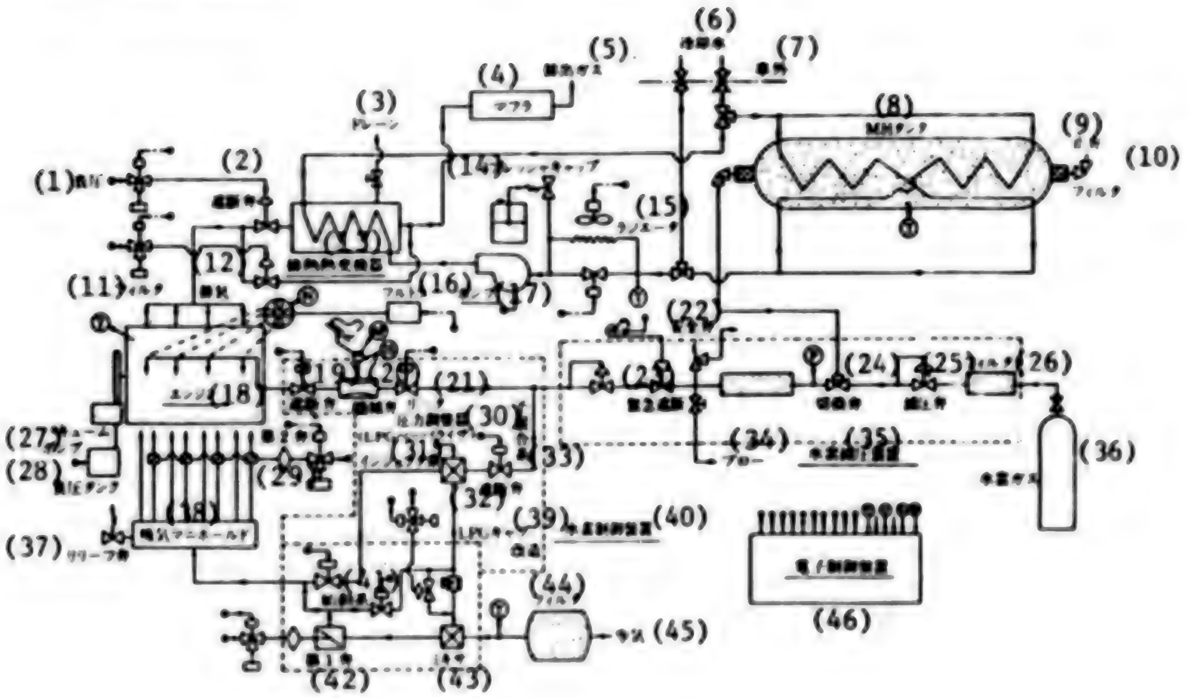


Chart 4. Control system

Key:

(1) Negative pressure
(2) Cut off valve
(3) Drain
(4) Muffler
(5) Exhaust gas
(6) Cooling water
(7) Outside the car
(8) MH tank
(9) Stoppage valve

(10) Filter
(11) Filter
(12) Exhaust air
(13) Exhaust heat exchanger
(14) Pressure cap
(15) Radiator
(16) Filter
(17) Pump
(18) Engine
(19) Cut off valve
(20) Machine valve
(21) Limiter
(22) Safety valve
(23) Emergency cut off valve
(24) Switch valve
(25) Decompression valve
(26) Filter
(27) Vacuum pump
(28) Negative pressure tank
(29) Second valve
(30) Pressure regulator (LPG vaporizer)
(31) Injector system
(32) Cut off valve
(33) Premix system
(34) Blow
(35) Hydrogen decompressor
(36) Hydrogen gas
(37) Relief valve
(38) Intake air manfold
(39) Remodeling of LPG cab
(40) Hydrogen control device
(41) Starter system
(42) First valve
(43) Mixer
(44) Filter
(46) Electronic control device

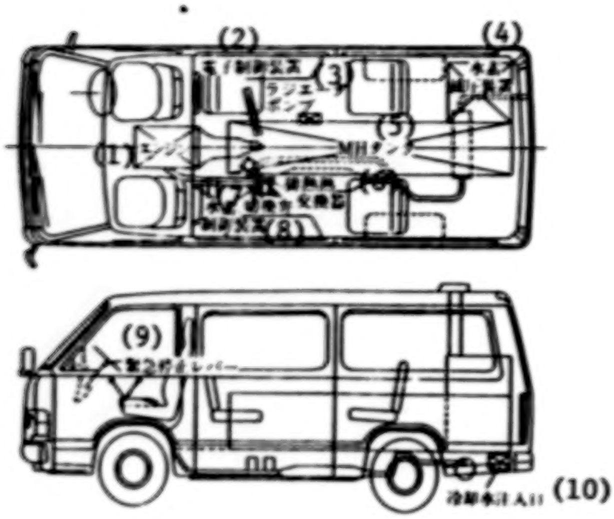
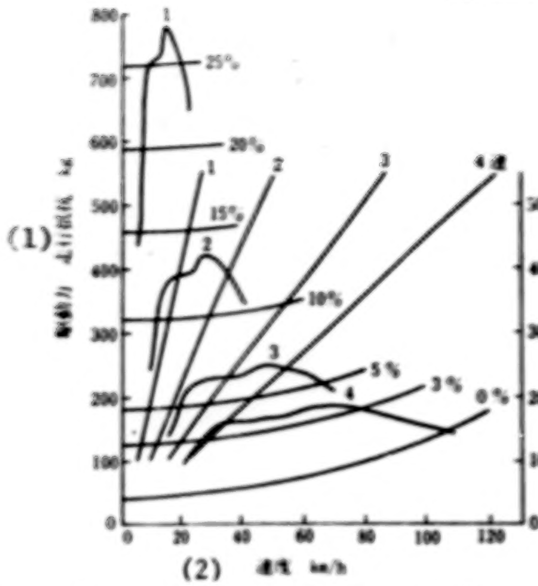


Chart 6. Configuration of components in the car

Key:

(1) Engine
(2) Electronic control device
(3) Radiator pump
(4) Hydrogen decompressor
(5) MH tank
(6) Exhaust heat exchanger
(7) Hydrogen control device
(8) Switch valve
(9) Emergency stop lever
(10) Cooling water injection outlet



			(12)	(13)
(4) (5)	60PS/4500rpm			
(4) (6)	11.6kgfm/3000rpm	1st	4.452	0.90
(7)	2780kg	2nd	2.398	0.90
(8)	0.015	3rd	1.414	0.90
(9)	0.65	4th	1.000	0.95
(10)	3.0m²	Rev	4.472	
(11)	0.313m	Dif	5.286	

Chart 7. Predicted Driving Performance Curve

Key:
- (1) Drive power, resistance to driving kg
- (2) Speed km/h
- (3) Engine rpm
- (4) Engine
- (5) Maximum output
- (6) Maximun torque
- (7) Total weight of car
- (8) Rolling resistance coefficiency
- (9) Air resistance coefficiency
- (10) Front cast shadow area
- (11) Tire efficiency radius
- (12) Speed change ratio
- (13) Transmission efficiency

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